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Air Pollutant Control Techniques for Phosphate Rock Processing Industry

PEDCo-Environmental, Inc, Cincinnati, OH

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Environmental Protection Agency, Research Triangle Park, NC Office of Air Quality Planning and Standards

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16. ABSTRACT

This document provides information needed by State and local pollution control agencies for development of regulations for control of particulate emissions from phosphate rock processing plants. Information on process and particulate emission control equipment is included for phosphate rock dryers, calciners, grinders, and ground rock handling equipment. Cost and economic information is given for both new and retrofitted facilities, and environmental impacts are presented for different levels of emission control. Results of emission measurements performed by EPA at phosphate rock dryers, calciners, and grinders are tabulated and presented with brief descriptions of the facilities tested. EPA particulate emission test methods are also briefly described.

Information presented in the document is summed up in an objective discussion of regulatory options and enforcement aspects of potential regulations.

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OAQPS GUIDELINE SERIES

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Mr. Lee L. Beck was the Project Officer for the Environmental Protection Agency.

1.0 INTRODUCTION

This document contains information on the control of particulate emissions from phosphate rock processing plants. Both typical and best demonstrated control techniques are discussed, and the cost and environmental impacts of several levels of emission control are presented for phosphate rock dryers, calciners, grinders, and ground rock handling systems. In addition to presenting data on emissions and their control, regulatory options and enforcement aspects of potential regulations for air emissions are discussed.

1.1 NEED TO REGULATE PHOSPHATE ROCK PROCESSING PLANTS

The United States is the largest producer and consumer of phosphate rock in the world, producing an estimated 40 percent and consuming approximately 35 percent of the world's supply. In 1977, the United States produced over 46 Tg (51 million tons) of phosphate rock. About 70 percent of domestic consumption of phosphate rock is as fertilizer. The other major uses are in animal feeds, detergents, electroplating and polishing of metals, insecticides, and medicines.

Demand for phosphate rock in the years 1985 and 2000, respectively, is projected to be 40.5 and 62.1 Tg (45 and 69 million tons) for the United States and 146 and 348 Tg (162 and 387 million tons) for the rest of the world.

The phosphate rock processing industry presents a significant potential contribution to air pollution for two reasons. First, of course, is the large volume of material handled. Any step in which the phosphate rock is handled in the dry state presents a potential for emission of particulate matter. In addition, many of the processes employed in preparation of the rock; drying, calcining, grinding, and pneumatic materials transfer, use large volumes of air which, at the process exhaust, contain suspended particulates. The environmental effects of particulate emissions have been investigated by the Environmental Protection Agency (EPA) and have been determined to pose a significant threat to public health and welfare.

1.2 SOURCES AND CONTROL OF EMISSIONS

Operations which are discussed in this document are drying, calcining, ground rock transfer systems, and grinding. The bases for selection of these processing steps are: (1) significant potential for emissions, and (2) availability of technology to insure significant reduction of emissions. Each operation is discussed separately.

Drying is chosen for study as a major emissions source largely because of the importance of this operation in preparing Florida rock for fertilizer manufacture. About 96 percent of the rock produced in Florida is dried. Dryers are also used to some extent in the other processing areas, usually for processing rock destined for shipping or manufacture of fertilizers. Since the future growth of fertilizer industries (estimated at four percent per year) is dependent on supplies of phosphate rock, it is likely that demand for additional dryers will parallel demand for additional fertilizer. Drying presents a potential for emission of particulate matter because of attrition of the rock in the dryer and the large volume of air which sweeps through the dryer and must be vented to the atmosphere. The magnitude of the potential for emissions can be estimated by considering a typical rock dryer, processing 225 Megagrams (250 tons) of rock per hour, discharging 40.8 dry standard cubic meters of exhaust gases per second (85,000 dry standard cubic feet per minute). The average loading of particulate matter in the air stream is about 7 grams per standard cubic meter (3 grains per standard cubic foot). The potential annual emission for such a dryer is 7,762 Mg (8,625 tons) per year of particulate matter, assuming 90 percent operating factor and no control of emissions. As detailed in Chapter 3, technology is available to ensure significant reduction in these emissions.

The potential growth of calcining operations is also substantial, since any new fertilizer installation processing North Carolina or Western phosphate rock will require a calciner. Processing of rock from these two reserves is likely to expand since the reserves in both locations are extensive and are not developed to their potential. As a source of emission of particulate matter, a typical calciner processes 54 Mg (60 tons) of rock per hour exhausting 19.2 dry standard cubic meters per second (40,000 dscfm) of gases with a particulate loading of 7 to 11 grams per dry standard cubic meter (3 to 5 grains per dry standard cubic foot). The potential annual emissions rate for such a calciner is over 3,600 Mg (4,000 tons) per year, assuming a 90 percent operating factor and no emission control. Technology is available to permit significant reduction in the uncontrolled emissions rate.

Projected growth of grinding operations can also be expected to parallel the growth of fertilizer production. The potential for contribution to air pollution is substantial; a typical milling installation grinds 45 Mg (50 tons) of rock per hour, exhausting 2.16 dry standard m^3/s (4,500 dscfm) of gases with a particulate loading of 7 grams per dry standard cubic meter (3 grains per dry standard cubic foot) before emission control. The annual emissions potential for such a unit is about 414 Mg (460 tons) per year, assuming 90 percent operating factor and no attempt at emission control. Technology is available for significant reduction of this potential emission.

Ground phosphate rock is usually transferred pneumatically, with the exhaust of the transfer system controlled by a fabric filter. Though the mass emissions rate from ground rock transfer systems has not been sampled, visible emission measurements have shown that these systems can be operated without a visible exhaust, thus preventing significant emissions from this potential source.

2.0 SOURCES AND TYPES OF EMISSIONS

2.1 GENERAL

The phosphate rock industry consists of mining and rock processing operations centered close to ore reserves.

Phosphate rock mines of significant commercial importance are located in Florida, North Carolina, Tennessee, Idaho, Wyoming, Utah, and Montana.[1] Table 2-1 lists producers of phosphate rock and their respective capacities. In 1975, 21 producers were spread over 36 locations and employed a total of about 12,000 people.[3,4] Table 2-2 presents the total domestic production and shipments for years from 1965 to 1977. Future production is expected to grow at an annual rate of about four percent.[5]

Nearly three-quarters of the domestic production capacity is located in Florida. In 1976, Florida and North Carolina produced some 37.5 Tg (41.3 million tons), accounting for more than 84 percent of the total domestic production.[6]

Phosphate rock is used primarily to produce phosphatic fertilizers. About 20 percent of the rock is converted to other products, such as elemental phosphorus and defluorinated animal-feed supplements. Thirty percent is exported.[7]

Table 2-1. PHOSPHATE ROCK PRODUCERS AND PLANT CAPACITIES - 1977[2]

Company	Location	Capacity, Tg/yr	(10^3 tpy)
Agrico Chemical Co.	Fort Green, Fla	3.17	(3,500)
	Pierce, Fla	5.44	(6,000)
Beker Industries	Dry Valley, Idaho	0.91	(1,000)
Borden Chemicals	Tenoroc, Fla.	0.91	(1,000)
Brewster Phosphates	Brewster, Fla.	5.71	(6,300)
Cominco-American	Garrison, Mont.	0.25	(275)
Cuyama Phosphate	New Cuyama, Calif.	0.45	(500)
Gardinier, Inc.	Ft. Meade, Fla.	1.81	(2,000)
W. R. Grace	Bonny Lake, Fla.	2.27	(2,500)
	Hooker's Prairie, Fla.	2.54	(2,800)
Hooker Chemical Co.	Columbia, Tenn.	0.45	(500)
International Minerals and Chemicals	Bonnie, Fla.	2.72	(3,000)
	Kingsford, Fla.	8.62	(9,500)
Mobil Chemical Co.	Nichols, Fla.	1.36	(1,500)
	Ft. Meade, Fla.	2.90	(3,200)
Monsanto Industrial Chemical Co.	Ballard, Idaho	0.91	(1,000)
	Columbia, Tenn.	0.91	(1,000)
Occidental Chemical Co.	White Springs, Fla.	4.54	(5,000)
Poseidon Mines	Lakeland, Fla.	0.54	(600)
Presnell Phosphate	Columbia, Tenn.	0.45	(500)
George Relyea Co.	Garrison, Montana	0.09	(100)
J. R. Simplot Co.	Conda, Idaho	0.41	(450)
	Ft. Hall, Idaho	1.81	(2,000)
Stauffer Chemical Co.	Cherokee, Utah	0.73	(800)
	Vernal, Utah	0.54	(600)
	Mt. Pleasant, Tenn.	0.54	(600)
Swift Chemical Co.	Bartow, Fla.	2.72	(3,000)
T-A Minerals Corp.	Rock City, Fla.	0.45	(500)
Texasgulf, Inc.	Lee Creek, N.C.	4.54	(5,000)
U.S.S. Agri-Chem	Ft. Meade, Fla	1.81	(2,000)
TOTAL		60.52	(66,725)

Table 2-2. PRODUCTION AND SHIPMENTS OF PHOSPHATE ROCK[6]

Year	Production		Shipments	
	Tg	(10^3 tons)	Tg	(10^3 tons)
1965	26.74	(29,482)	26.34	(29,039)
1966	35.41	(39,044)	33.05	(36,443)
1967	36.01	(39,700)	34.32	(37,835)
1968	37.41	(41,251)	33.84	(37,319)
1969	34.22	(37,725)	33.31	(36,730)
1970	35.14	(38,739)	35.16	(38,765)
1971	35.26	(38,886)	36.54	(40,291)
1972	37.03	(40,831)	39.69	(43,755)
1973	38.22	(42,137)	40.85	(45,043)
1974	41.44	(45,686)	43.93	(48,435)
1975	44.28	(48,816)	43.93	(48,439)
1976[a]	44.13	(48,659)	39.21	(43,230)
1977[a]	46.50	(51,266)	46.60	(51,383)

[a] Information on 1976 and 1977 production and shipments was obtained from Mr. Ed Harre, Tennessee Valley Authority, National Fertilizer Development, Muscle Shoals, Alabama. April 17, 1978.

The ingredient of the rock that is of economic interest is tricalcium phosphate [$Ca_3(PO_4)_2$], also known in the industry as bone phosphate of lime (BPL) because the first commercial source of this chemical was charred animal bones. The rock is usually graded on the basis of its BPL content, e.g., 68 BPL rock contains 68 percent by weight of tricalcium phosphate. The final product contains roughly 68 to 74 percent BPL.[8]

Chemically, phosphate rock may be considered to contain a substituted fluorapatite. The basic fluorapatite structure is represented as $3Ca_3(PO_4)_2 \cdot Ca_2F$.[9] Nearly all phosphate ores contain a modified form of this structure in which some of the phosphate is replaced by fluoride and carbonate.[10] The total fluoride content of typical phosphate rock is approximately 4 to 5 percent by weight, expressed as fluorine.[11]

Commercial phosphate rock contains 30 to 38 percent P_2O_5 plus a variety of impurities such as iron, aluminum, magnesium, silica, carbon dioxide, sodium, potassium, and sulfates.[12]

The hardness and organic content of phosphate rock determine the way it is mined and processed. Generalized flow diagrams for mining and processing operations in Florida, Tennessee, and the Western States are presented in

Figures 2-1, 2-2, and 2-3, respectively. Only those phosphate rock operations associated with the manufacture of fertilizer were investigated for development of the control techniques document. Drying, calcining, and grinding are the major emission sources for which control techniques were studied. Materials handling and storage and wet grinding are also discussed.

2.2 MINING AND BENEFICIATION

Hard rock is found in the western states. Its hardness generally decreases the further north the ore is located. Conventional earth moving equipment is used to remove the first 1.5 to 15 meters (5 to 50 feet) of earth (overburden) to expose the layer of phosphate rock. Hard rock found in Utah is removed by blasting with dynamite. Softer rock is removed by a "ripper", a toothed implement that gouges and breaks the rock from the surface. In Montana, two small underground mines are also operated for removal of phosphate rock.

Western rock is usually hauled to the rock processing plant by truck. The first processing step separates the rock from impurities; this process is called beneficiation. The sequence of steps in the beneficiation process at plants mining western hard-rock ores differs from plant to plant depending on the hardness of the ore and the end use

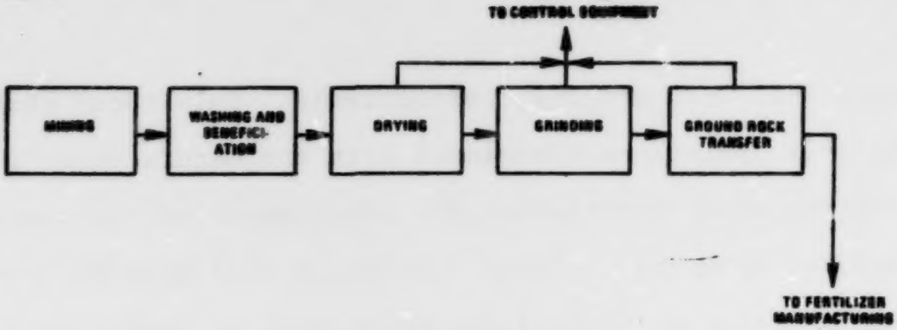
TO CONTROL EQUIPMENT
MINING
WASHING AND BENEFICI-ATION
DRYING
GRINDING
GROUND ROCK TRANSFER
TO FERTILIZER MANUFACTURING

Figure 2-1. Generalized flow scheme for Florida phosphate rock.

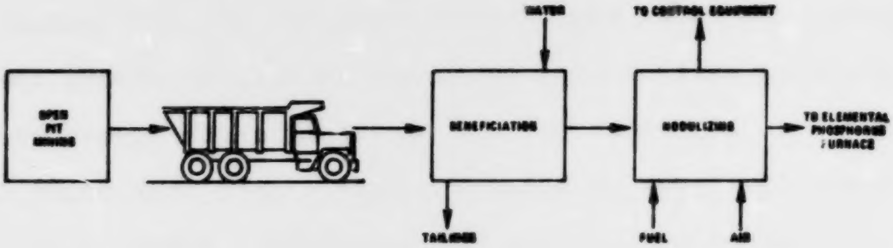
WATER
TO CONTROL EQUIPMENT
OPEN PIT MINING
BENEFICIATION
NODULIZING
TO ELEMENTAL PHOSPHORUS FURNACE
TAILINGS
FUEL
AIR

Figure 2-2. Generalized flow scheme for Tennessee phosphate rock.

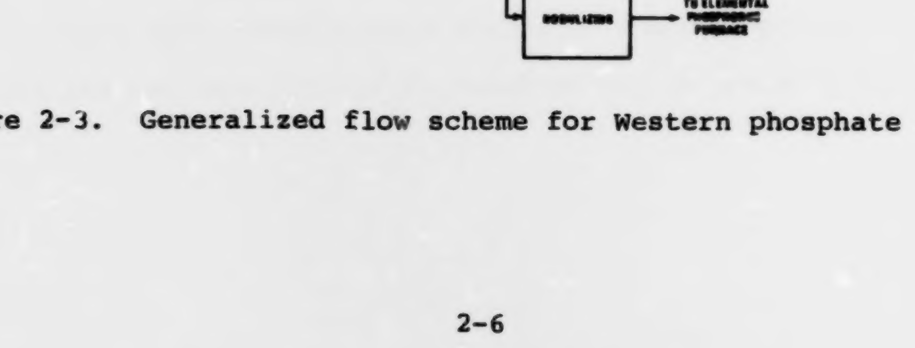
TO CONTROL EQUIPMENT
WATER
MINING
BENEFICI-ATION
CALCINING
GRINDING
GROUND ROCK TRANSFER
FUEL
TO CONTROL EQUIPMENT
AIR
SLIME
TO FERTILIZER MANUFACTURING
NODULIZING
TO ELEMENTAL PHOSPHORUS FURNACE

Figure 2-3. Generalized flow scheme for Western phosphate rock.

of the rock. Crushing is employed at some western mines; however, in the United States as a whole, it is only used on only 12 percent of the rock mined. In the beneficiation plant, primary crushers first reduce the ore to less than 0.6 centimeter (1/4 inch). (This practice is particularly common in the southern sector of the West.) Further size reduction is accomplished in several steps, the last of which is a slurry-grinding process that uses a wet rod mill to reduce the ore to particles about the size of beach sand. The slurry is then size-classified in hydrocyclones in which centrifugal force is used to separate product-size material from the tailings (clay and sand particles smaller than about 100-mesh). The ore is then filtered from the slurry and conveyed to the next processing step. The tailings are discarded.

The deposits in Tennessee consist of small pockets of brownish phosphate sands surrounded by brown silica sand. Draglines and small power shovels are used to mine the phosphate sand, which is then hauled by truck or rail to the processing plants. A typical Tennessee beneficiation process consists of a unit called a "log-washer," in which the ore is slurried with water to break up any large agglomerated masses, then sent to a hydrocloning unit for size classification. The product-size fraction then goes to nodulizing kilns, where it is prepared for feeding to electric arc furnaces to produce elemental phosphorus.

The Florida and North Carolina deposits consist of a consolidated mass of phosphate pebbles and clays known as matrix, which is deposited in a discrete layer of considerable extent. Mining is conducted by stripping overburden from the matrix deposits and removing the matrix layer by use of electrically driven draglines. After extraction, the ore is normally transported by conveyor belt to washing and beneficiating operations.

No air pollutants are generated during either the mining or beneficiation processes except at a few plants that mine the hard, dry rock in the southern part of the western reserves. Because of the dry climate in that area, rock mining and hauling produce dust similar to that generated in rock quarrying operations. The ground moisture content is sufficient in most phosphate rock mining operations to prevent emissions, and because beneficiation is always conducted in a water slurry, it does not produce air emissions.

After it leaves the beneficiation plant, ore must be dried, calcined, or nodulized before it can be further processed. The process used depends on the organic content of the ore and the ultimate product for which it is destined. Since Florida rock is relatively free of organics, it is dried by simply heating it to about 394°K (250°F) to drive off free water. Rock from other reserves in the nation, however, contains organics, and must be calcined by heating to 1000° to 1150°K (1400° to 1600°F). If the organics are not removed, they cause a slime that hinders filtration during the manufacture of wet-process phosphoric acid, which is the starting material for phosphate fertilizer. When the nodulizing process is required, the ore is heated to 1500° to 1700°K (2200° to 2600°F). This process not only drives off water, carbon dioxide, and organic matter, but also causes the ore to fuse into larger lumps suitable for feeding to the electric arc furnace used in the manufacture of elemental phosphorus. Only Tennessee ore and some western ores are nodulized.

2.3 DRYING

Phosphate ores are dried in direct-fired dryers, i.e., the combustion products are placed in direct contact with the ore. Most dryers are fired with natural gas, No. 2 oil, or No. 6 fuel oil; many are equipped to burn more than one type of fuel. Throughout the late 1960's and early 1970's the trend was toward fuel oil, usually No. 6. Although both rotary and fluidized-bed units are employed, the rotary is more common. Figures 2-4 and 2-5 are typical schematics of

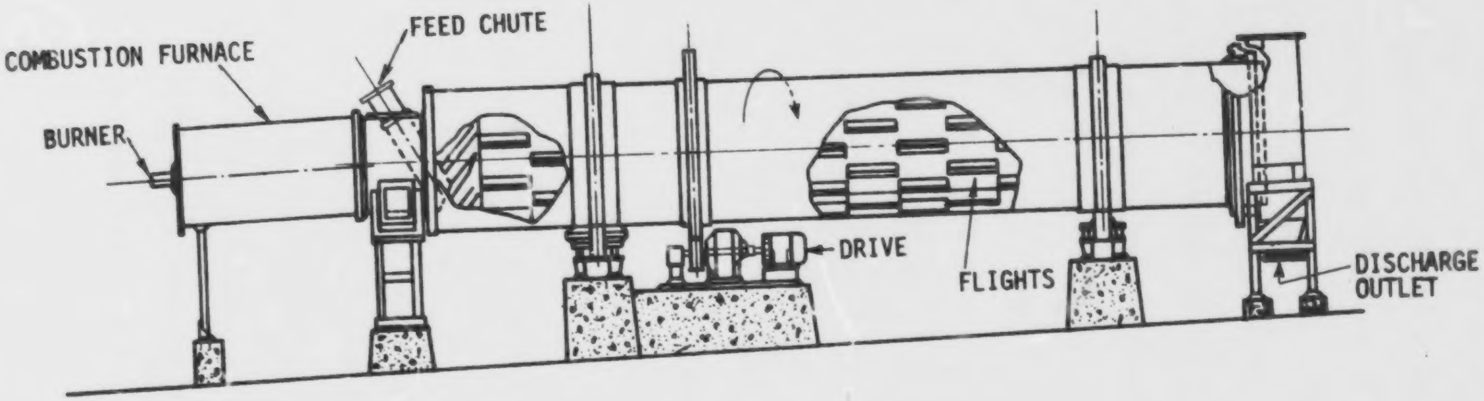
COMBUSTION FURNACE
BURNER
FEED CHUTE
DRIVE
FLIGHTS
DISCHARGE OUTLET

Figure 2-4. Direct-fired, co-current, rotary dryer.

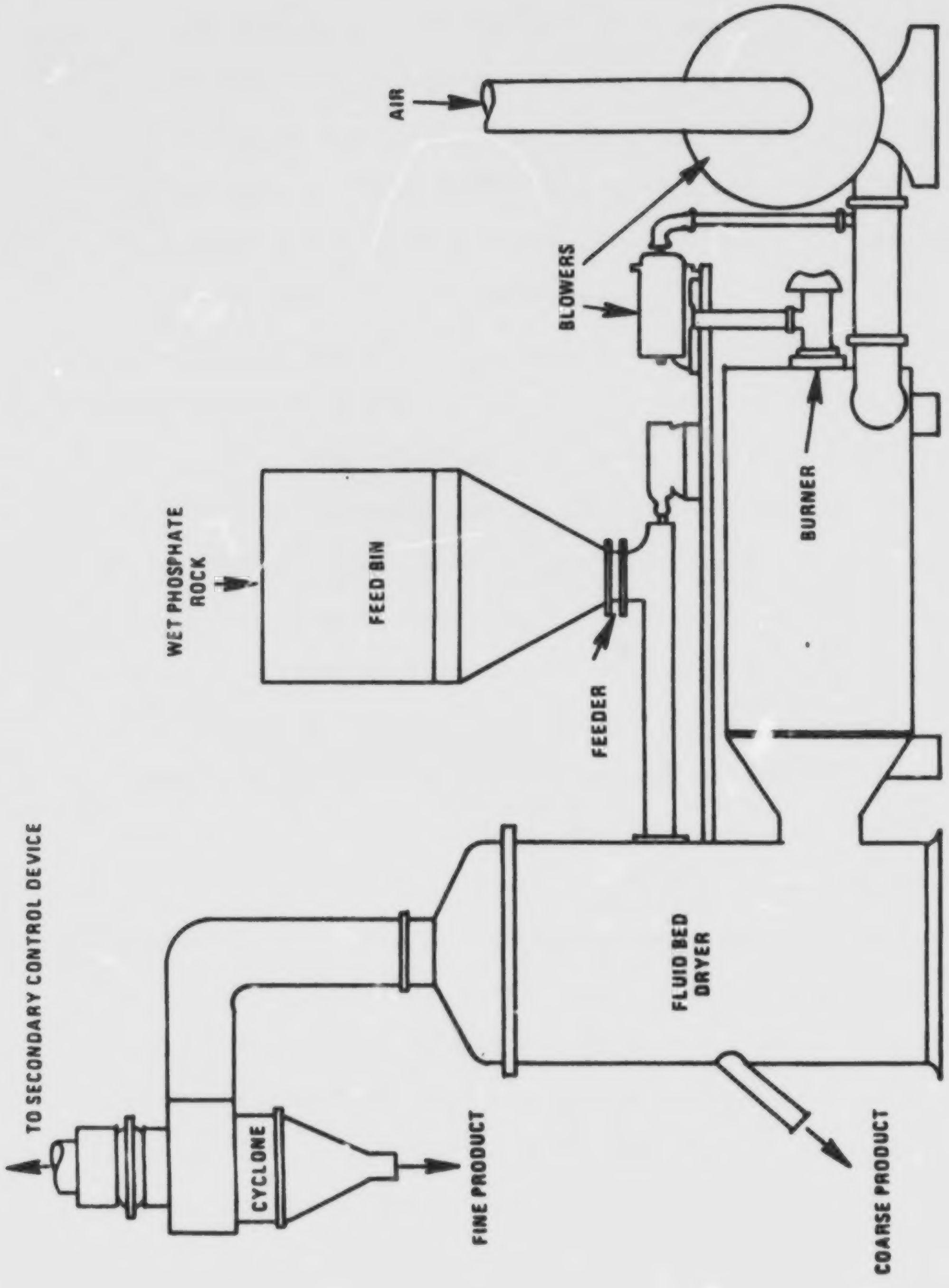
AIR
BLOWERS
WET PHOSPHATE ROCK
FEED BIN
FEEDER
BURNER
TO SECONDARY CONTROL DEVICE
CYCLONE
FINE PRODUCT
FLUID BED DRYER
COARSE PRODUCT

Figure 2-5. Fluid-bed dryer.

the two types of dryers. The ore is discharged when the moisture content reaches 1 to 3 percent, the percentage determined by the ultimate use of the ore. As shown in Table 2-3, capacities of dryers range from 4.5 to 320 Mg/h (5 to 350 tons/h), with 180 Mg/h (200 tons/h) a representative average. The newer installations tend to be larger units. Conservative operators minimize air usage to decrease fuel consumption and reduce the size and cost of air pollution control devices. Characteristics of emissions and exhausts from dryers are presented in Table 2-4.

Process variables that affect emissions from a phosphate rock dryer include the type of rock being processed (a factor at Florida plants only), fuel type, air flow rate, product moisture content, and in the case of a rotary dryer, speed of rotation. A unique situation regarding rock types in the Florida industry deserves some comment. The pebble rock described earlier receives much less washing than does the concentrate rock from the flotation processes and therefore has a higher clay content. Uncontrolled emissions from drying pebble rock are substantially higher than those resulting from drying ore from the flotation process.[14] This difference is recognized by the Florida Department of Pollution Control,[15] and variances have been granted to some operators when drying pebble rock and using scrubbers as the

Table 2-3. CAPACITIES AND GAS FLOW RATES FOR PHOSPHATE ROCK DRYERS[13]

Company	Location	Product rate, Mg/h (tons/h)	Type of facility	Stack gas flow rate, std. m^3/s (10^3 scfm)
Agrico Chemical	Pierce, Fla.	907 (1,000)	NR	378 (800)
Beker Industries	Conda, Idaho	57 (63)	Fluid-bed	12.7 (27)
Borden Chemical	Plant City, Fla.	136 (150)	Rotary	24.5 (52)
Brewster Phosphates	Bradley, Fla.	286 (315)[a]	NR	68.4 (145)[a]
Conserv, Inc.	Nichols, Fla.	100 (110)	NR	12.7 (27)
Freeport Chemicals	Uncle Sam, La.	181 (200) 181 (200)	Fluid-bed Fluid-bed	NR NR NR NR
Gardinier, Inc.	Ft. Meade, Fla.	178 (196)	NR	36.3 (77)
W. R. Grace & Co.	Bartow, Fla.	300 (330) 150 (165)	Rotary Fluid-bed	61.4 (130)[a]
Hooker Chemical	Columbia, Tenn.	19 (21)	Rotary[b]	8.5 (18)
IMC Corporation	Noralyn, Fla.	500 (550)[a]	NR NR	73 (155)[a]
IMC Corporation	Kingsford, Fla.	300 (333)	Fluid-bed	33 (70)
Mobil Chemical	Nichols, Fla.	317 (350) 317 (350)	Rotary Rotary	37 (78) 37 (78)
Occidental Chemical	White Springs, Fla.	220 (242)	Fluid-bed	44 (93)

(Continued)

Table 2-3 (continued). CAPACITIES AND GAS FLOW RATES FOR PHOSPHATE ROCK DRYERS[13]

Company	Location	Product rate, Mg/h (tons/h)	Type of facility	Stack gas flow rate, std. m^3/s (10^3 scfm)
Rocky Mtn. Phosphates	Garrison, Montana	4.5 (5)	Rotary[c]	NR NR
J. R. Simplot	Conda, Idaho	136 (150)	Rotary[d]	10.4 (22)
Stauffer Chemical	Leefe, Wyoming	50 (55)	Rotary	7.0 (15)
Stauffer Chemical	Vernal, Utah	24 (26) 24 (26)	Rotary Rotary	4.7 (10) 4.7 (10)
Swift Chemical	Bartow, Fla.	161 (178) 240 (265)	Rotary Fluid-bed	26.4 (56) 35.9 (76)
Texasgulf, Inc.	Aurora, N.C.	211 (233)	Fluid-bed	NR NR
U.S.S. Agri-Chem	Ft. Meade, Fla.	170 (187)	Rotary	NR NR

[a] Total for two dryers.

[b] This dryer operates at 477°K (400°F) (exit gas temperature).

[c] This dryer operates at 394 to 422°K (250°-300°F) (exit gas temperature).

[d] This dryer operates at 422°K (300°F) exit gas temperature.

NR - not reported.

Table 2-4. CHARACTERISTICS OF EXHAUST GAS FROM FLUID-BED AND ROTARY DRYERS

Exhaust flow rate	0.13 - 0.23 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$	250-450 scfm/tons/h product
Temperature	394 - 422°K	250-300°F
Moisture	8-30% v	8-30% v
Uncontrolled mass emissions	2-9 g/kg product	4-18 lb/ton product
Grain loading	7-11 g/dry std. m^3	3-5 gr/dscf
Particle size distribution[16]		98% < 10 μm 92.9% < 5 μm 73.8% < 2 μm 39.9% < 1 μm 7.2% < 0.5 μm

control device. Emission control techniques are discussed in more detail in Chapter 3.

2.4 CALCINING

The most common type of calciner is the fluidized-bed unit (illustrated in Figure 2-6); rotary calciners are also used. Calciners operate at much higher temperatures than dryers and they require refractory linings. Also, as shown in Figure 2-5, the fluidized-bed dryer has an external combustion chamber from which the flue gases pass through the dryer, whereas the calciner (Figure 2-6) employs combustion within the bed of phosphate rock to achieve the higher temperatures. Calciners range in capacity from 18 to 63.5 Mg/h (20 to 70 tons/h); a representative average is about 45 Mg/h (50 tons/h). As noted for the dryers, the newer calciner installations also tend to be of larger capacity. Table 2-5 summarizes the production rate and the volumetric flow rate for fluid-bed and rotary calciners. Table 2-6 presents the characteristics of exhaust gases from calciners.

2.5 GRINDING

Grinding is widely employed in the processing of phosphate rock. After drying or calcining, these fine pulverizing mills produce a product of talcum powder consistency. These pulverizing mills or grinders (either

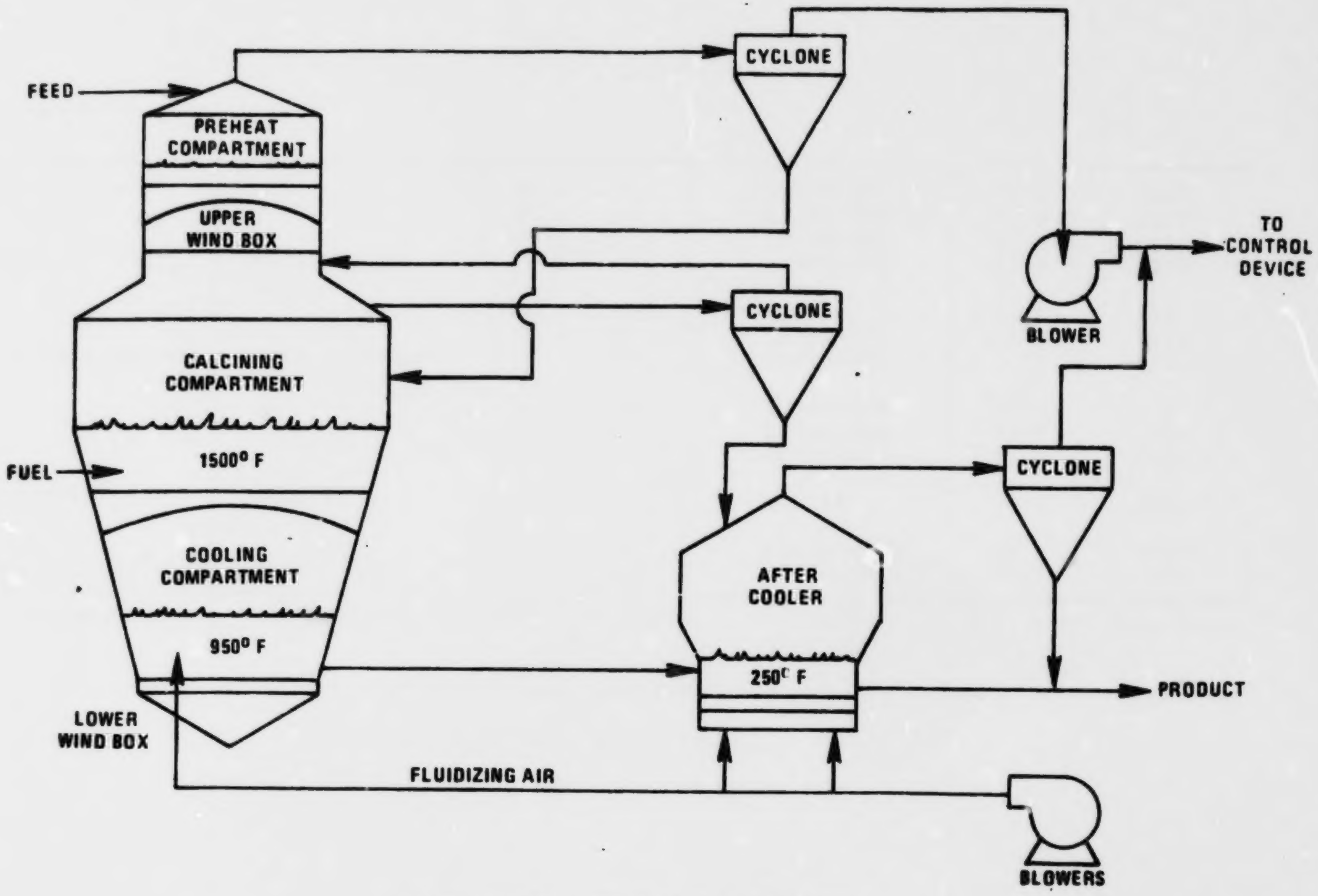
FEED
PREHEAT COMPARTMENT
UPPER WIND BOX
CALCINING COMPARTMENT
FUEL
1500° F
COOLING COMPARTMENT
950° F
LOWER WIND BOX
FLUIDIZING AIR
CYCLONE
CYCLONE
CYCLONE
AFTER COOLER
250° F
BLOWER
TO CONTROL DEVICE
PRODUCT
BLOWERS

Figure 2-6. Fluid-bed calciner.

Table 2-5. CAPACITIES AND GAS FLOW RATES FOR PHOSPHATE ROCK CALCINERS (1975)[13]

Company	Location	Production rate, Mg/h (tons/h)	Type of calciner	Stack gas flow rate, std. m^3/s (10^3 scfm)
Beker Industries	Conda, Idaho	63.5 (70)	Fluid-bed	16.3 (34)
		63.5 (70)	Fluid-bed	18.9 (40)
Mobil Chemical	Nichols, Fla.	45 (50)	Rotary	26.0 (55)
J. R. Simplot	Pocatello, Idaho	32 (35)	Fluid-bed	11.8 (25)
		37 (41)	Fluid-bed	13.2 (28)
		50 (55)	Fluid-bed	27.4 (58)
Stauffer Chemical	Leefe, Wyoming	18 (20)	Fluid-bed	8.0 (17)
		18 (20)	Fluid-bed	8.0 (17)
		27 (30)	Fluid-bed	13.7 (29)
Texasgulf, Inc.	Aurora, N.C.	54.4 (60)	Fluid-bed	25.0 (53)
		54.4 (60)	Fluid-bed	25.0 (53)
		54.4 (60)	Fluid-bed	25.0 (53)
		54.4 (60)	Fluid-bed	25.0 (53)

Table 2-6. CHARACTERISTICS OF EXHAUST GASES FROM FLUID-BED AND ROTARY CALCINERS

Exhaust flow rate	0.26 - 0.52 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$	500-1000 scfm/ tons/h product
Temperature	394°K[a]	250°F[a]
Moisture content	6-25% v	6-25% v
Uncontrolled mass emissions	3-20 kg/Mg	6-40 lb/ton product
Grain loading	5-11 g/dry std. m^3	2-5 gr/dscf
Particle size distribution[17]		95.9% < 10 μm 81.2% < 5 μm 52.3% < 2 μm 26.2% < 1 μm 5.2% < 0.5 μm

Composition of emission from cyclone collectors[17]	
Calcium (CaO)	18.3 % by weight
Phosphorous (P_2O_5)	14.4
Silica (SiO_2)	35.5
Aluminum (Al_2O_3)	8.4
Iron (Fe_2O_3)	2.3
Magnesium (MgO)	0.1
Other	21.

[a] The rock is calcined at 760° to 870°C (1400° to 1600°F) but the exhaust gas is cooled in the upper windbox and preheat compartments of the calciner before discharge.

roller or ball mills) are used by all manufacturers to produce fertilizer.

Roller mills and ball mills reduce the phosphate rock to a fine powder--typically specified as 60 percent by weight passing a 200-mesh sieve. Roller and ball mills are about equally favored in the industry. A typical grinding circuit is illustrated in Figure 2-7.

The roller mill is composed of hardened steel rollers that rotate against the inside of a steel ring, as shown in Figure 2-8. Ore is fed into the mill housing by a rotary valve that prevents the escape of air into the feed system. The rock is scooped up from the floor of the housing by plows and directed into the path of the rollers, where it is ground between the rollers and the steel ring. Ground rock is swept from the mill by a circulating airstream. Some product size classification is provided by the "revolving whizzers" at the top of the housing. The average particle size leaving the mill can be controlled by varying the speed of revolution of the whizzers. Further size segregation is provided by the air classifier, which separates oversize particles from product-size particles and recycles the oversize portion to the mill. The product is separated from the carrying air stream by a cyclone and conveyed to ground-rock storage. The air stream is returned to the mill in a

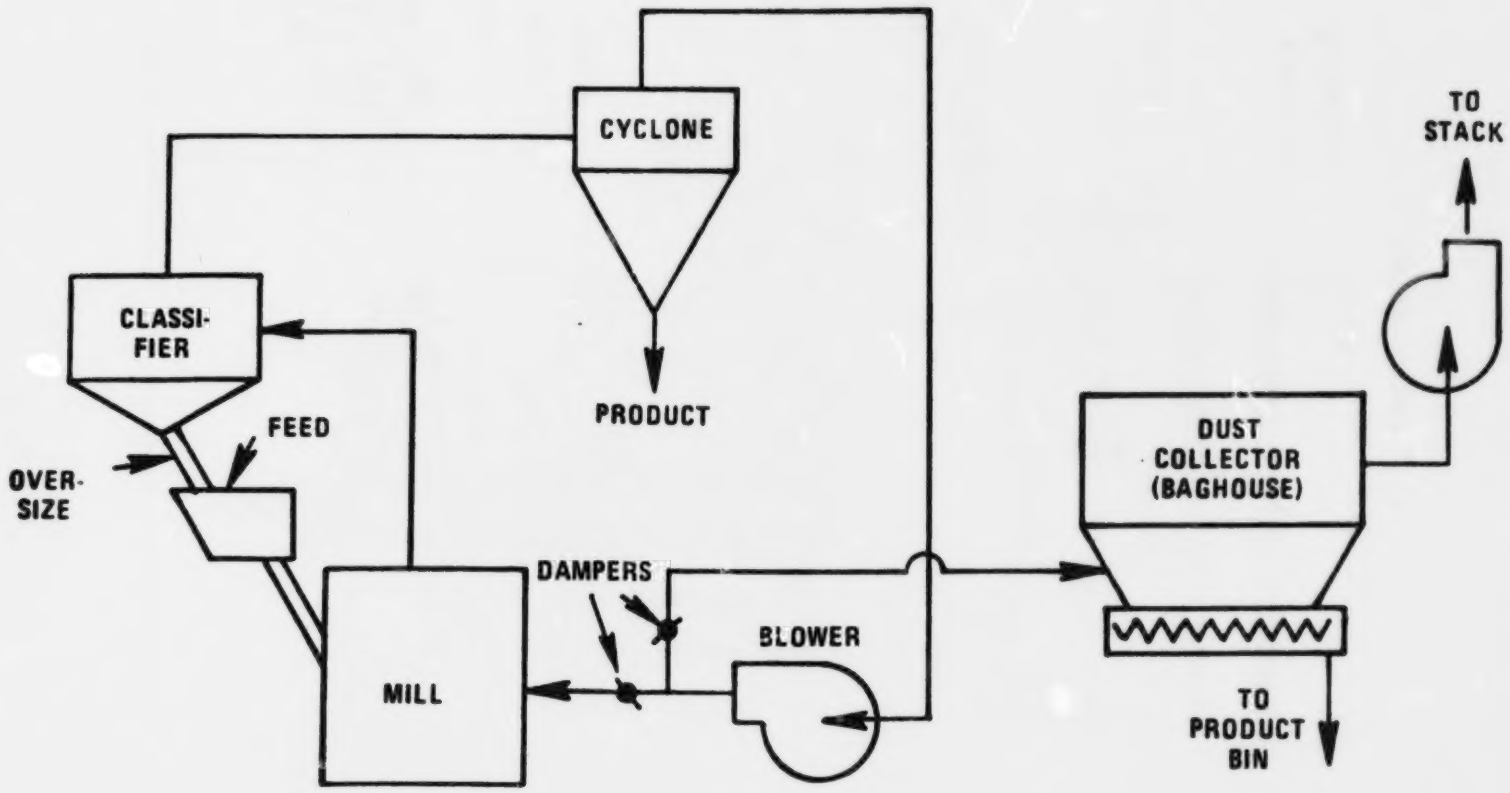
TO
STACK
CYCLONE
CLASSI-
FIER
PRODUCT
FEED
OVER-
SIZE
DUST
COLLECTOR
(BAGHOUSE)
DAMPERS
BLOWER
MILL
TO
PRODUCT
BIN

Figure 2-7. Typical grinding circuit.

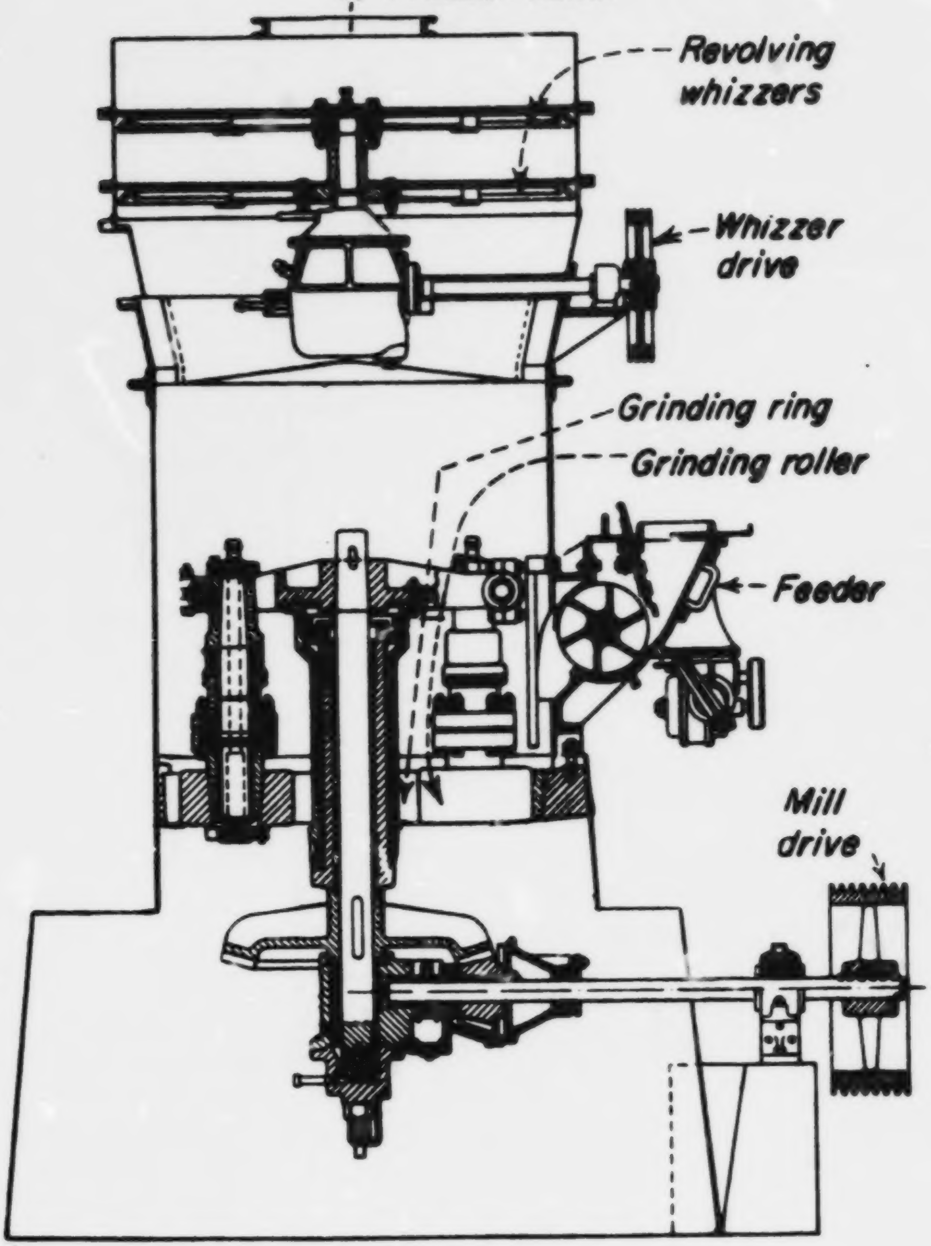
Product outlet
Revolving whizzers
Whizzer drive
Grinding ring
Grinding roller
Feeder
Mill drive

Figure 2-8. Roller mill.

closed loop, although there is a bleed stream from the system, as described below.

The ball mill is basically a drum revolving about an axis slightly inclined to the horizontal (Figure 2-9). The drum contains a large number of steel balls about 2.5 cm (1 in.) in diameter. Rock is charged into the mill through a rotary valve, ground by attrition with the balls, and swept from the mill by a circulating air stream, as described above for roller mills.

Roller and ball mills are operated slightly below atmospheric pressure to avoid the discharge of fugitive rock dust into the air. As a result, atmospheric air infiltrates the circulating streams. This tramp air is discharged from the circuit, through a dust collector, to the atmosphere. Mill capacities range from 13.6 Mg/h (15 tons/h) of phosphate rock for a smaller roller mill to about 236 Mg/h (260 tons/h) for a large ball mill. A typical mill has a capacity of 45 Mg/h (50 tons/h). Because roller mills are usually limited to about 68 Mg/h (75 tons/h) per unit many operators install several in parallel rather than a single large ball mill. No clear trend toward either method of grinding is evident. The volume of the tramp air discharge stream is more dependent upon the design and construction of the grinding circuit than on the capacity of the mill. For

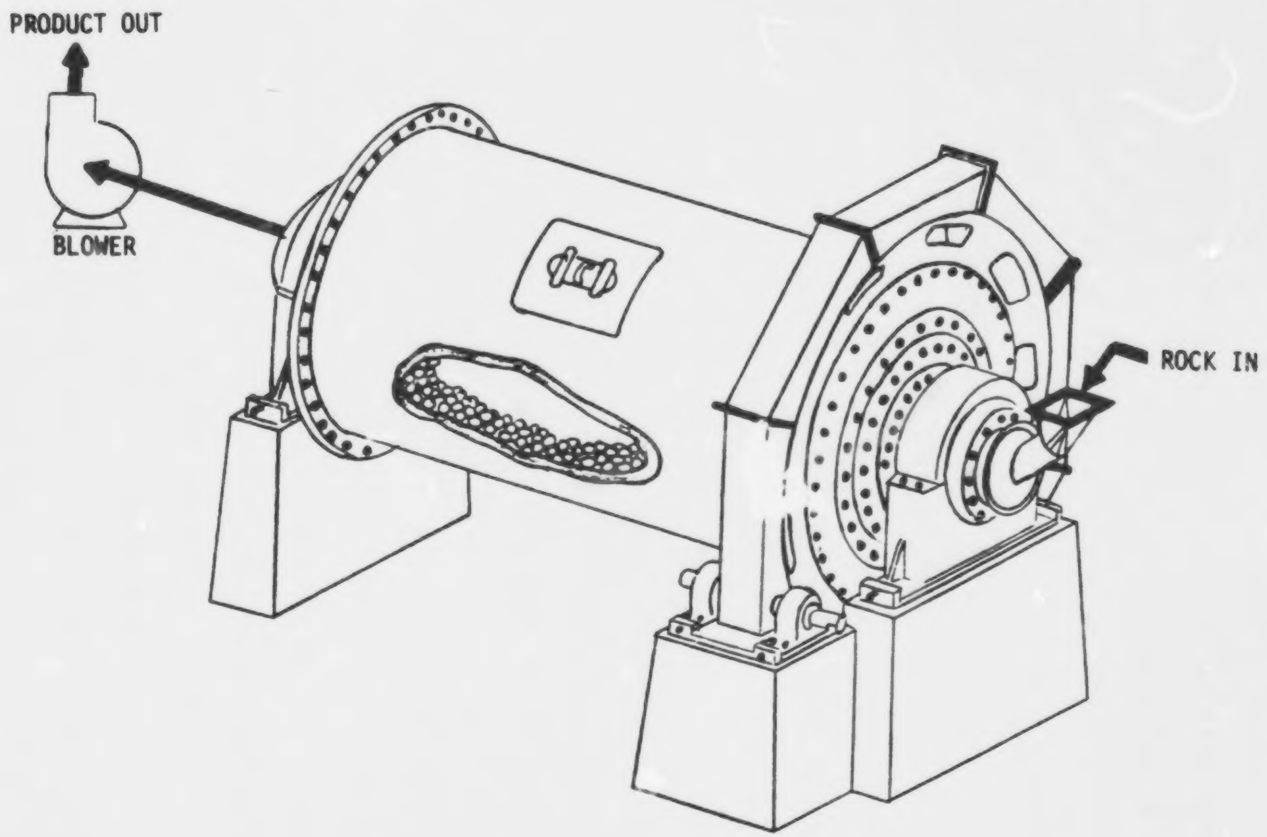
PRODUCT OUT
BLOWER
ROCK IN

Figure 2-9. Rotary ball mill.

example, it would not be unusual for a 136 Mg/h (150 tons/h) mill to discharge 8.97 dry std. m^3/s (19,000 dscfm), whereas a 227 Mg/h (250 tons/h) unit might discharge 4.72 dry std. m^3/s (10,000 dscfm). Table 2-7 shows the characteristics of the exhaust gases from grinding operations. Table 2-8 summarizes the production rate and volumetric flow rate for several types of mills.

2.6 MATERIALS HANDLING AND STORAGE

Provision is usually made to convey and/or store the rock between each of the operations described. The materials handling and storage operations employed by the phosphate rock industry range from truck hauling and open storage to sophisticated pneumatic transfer systems and silos. Normal methods of conveying ore from the mines to beneficiation plants have been mentioned earlier in this report. The handling and storage procedures commonly employed at other steps in the various processes will now be discussed.

Beneficiated rock is commonly stored wet in open piles. Several methods are used to reclaim the material from the piles, such as skip loaders, underground conveyor belts, and above-ground reclaim trolleys. The reclaimed ore is normally conveyed to the next processing step (drying, calcining, or nodulizing) by either open or weather-protected conveyor belts.

Table 2-7. CHARACTERISTICS OF EXHAUST GASES FROM PHOSPHATE ROCK GRINDERS

Exhaust flow rate	31-83 wet std. $m^3 \cdot s^{-1}/kg \cdot h^{-1}$	60-160 scfm/ tons/h product
Temperature	310-339°K	100-150°F
Moisture	Up to 9% v	Up to 9% v
Uncontrolled mass emissions	<3.5 kg/Mg	<7.0 lb/ton product
Grain loading	7-11 g/dry std. m^3	3-5 gr/dscf

Dust composition[17]	
Calcium (CaO)	45.5 % by weight
Phosphorous (P_2O_5)	32.5
Silica (SiO_2)	11.0
Aluminum (Al_2O_3)	2.0
Iron (Fe_2O_3)	0.8
Magnesium (MgO)	0.7
Other	7.5

Table 2.8 CAPACITIES AND GAS FLOW RATES FOR PHOSPHATE ROCK GRINDERS (1975)[13]

Company	Location	Production rate, Mg/h (tons/h)	Number of mills	Type of mill	Stack gas flow rate, m^3/s (10^3 scfm)
Agrico Chemical	Pierce, Florida	157 (173)	6	Roller	9.63 (20.4)
Beker Industries	Conda, Idaho	54.5 (60) 68 (75)	1 2	Ball Ball	1.8 (3.8)
Brewster Phosphates	Bradley, Florida	NR	2	Roller	3.4 (7.1)
Farmland Industries	Bartow, Florida	100 (110)	1	Ball	6.8 (14.4)
Freeport Chemicals	Uncle Sam, La.	363 (400)	2	Ball	NR
Gardinier, Inc.	Tampa, Florida	213 (235)	1 5	Roller Roller & ball	4.5 (9.6) 15.3 (32.3)
W. R. Grace and Co.	Bartow, Florida	40 (45) 141 (155)	3 2	Roller Ball	7.7 (16.3) 5.8 (12.2)
IMC Corporation	Noralyn, Florida	218 (240)	7	Roller & ball	18.9 (40.0)
IMC Corporation	Kingsford, Florida	100 (110)	3	Roller	9.9 (21.0)
Mobil Chemical	Nichols, Florida	190 (209)	4	Roller	3.8 (8.0)
Occidental Chemical	White Springs, Fla.	112.5 (124)	1	Ball	6.4 (13.6)
Royster Company	Mulberry, Florida	59 (65)	2	Roller & bowl	3.0 (6.3)
J. R. Simplot	Pocatello, Idaho	91 (100)	6	Roller	16.1 (34.0)
Stauffer Chemical	Leefe, Wyoming	36 (40)	3	Roller	NR
Swift Chemical	Bartow, Florida	40 (45)	3	Roller	2.8 (6.0)
Texasgulf, Inc.	Aurora, N.C.	136 (150)	2	Ball	11.3 (24.0)
U.S.S. Agri-Chem	Bartow, Florida	40 (45)	3	Roller	4.3 (9.1)
U.S.S. Agri-Chem	Ft. Meade, Florida	68 (75)	4	Roller	4.6 (9.8)

[a] Total for all mills.

NR = Not reported.

Rock discharged from the rock dryers or calciners is usually conveyed to storage silos on weather-protected conveyors. From the silos, the rock is either transported to the consumers in rail cars and trucks or is conveyed to grinding mills, which prepare the rock for feed to fertilizer plants.

Ground rock is usually conveyed in some type of totally enclosed screw conveyor, in a dust pump system, or in an air slide system. The screw conveyor consists of a long screw, driven at one end and enclosed in a tube or covered trough. Ground rock fed into one end of the tube is carried along the flights of the screw and discharged at the opposite end. The dust pump system employs an aerated bin to generate a continuous stream of fluidized rock. The rock dust is then blown from the ground-rock surge bin to the receiving units through pipelines. Provision must be made to vent the conveying airstream at the discharge end. Potential emissions from typical materials-handling and storage systems are estimated at 1.0 kg/Mg (2 lb/ton) of rock handled.[14] The air slide system, illustrated in Figure 2-10, is composed of a rectangular duct that is separated into upper and lower segments by porous tile. The duct is inclined downward from the feed end to the discharge. Rock dust is fed into the upper segment of the duct and low-pressure air is

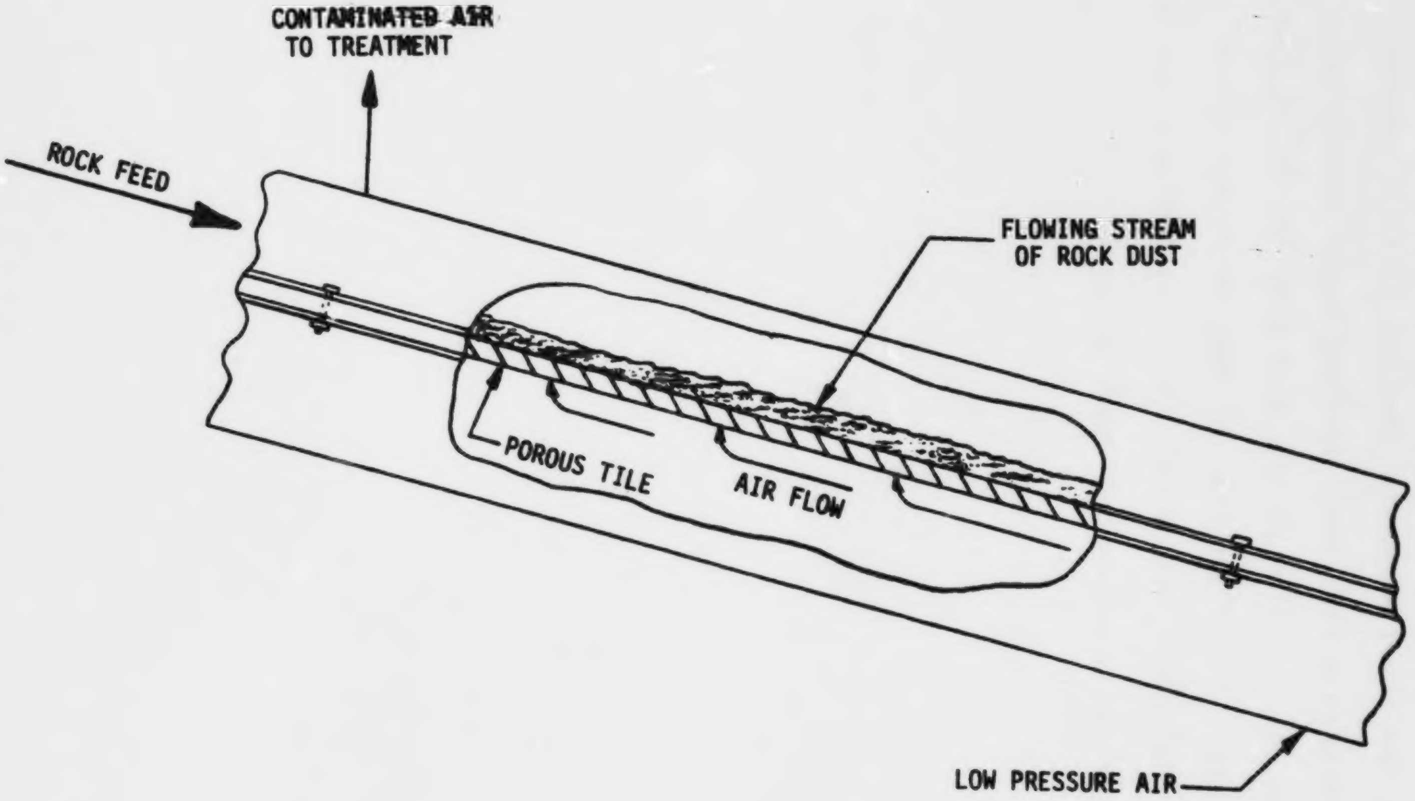
CONTAMINATED AIR
TO TREATMENT
ROCK FEED
FLOWING STREAM
OF ROCK DUST
POROUS TILE
AIR FLOW
LOW PRESSURE AIR

Figure 2-10. Typical air slide conveyor.

blown into the lower segment. The air diffuses upward through the porous tile into the rock dust, thereby assisting the gravity flow of the rock down the incline to the discharge end. Provision must be made to inject air at intervals throughout the length of a long conveyor and to purge the excess air from the upper segment.

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3.0 APPLICABLE EMISSION REDUCTION TECHNIQUES

The sequential operations in a phosphate rock processing plant require the application of several systems to control emissions. Operations that require some type of emission control are drying, calcining, conveying and storage of dry rock, grinding, and conveying and storage of ground rock. Generally, each operation has its own emission control system.

3.1 MINING AND BENEFICIATION

Over 98 percent of the phosphate rock produced in the United States is mined in areas where the ground moisture content is high enough to preclude particulate emissions during extraction of the ore. In the relatively dry areas, where ground moisture content is not sufficient to prevent emissions (such as the hard-rock areas of Utah and Wyoming) mining operations generate particulate emissions during blasting and in the handling of overburden and ore body. The active mining area is wetted with water from tank trucks to minimize these emissions. Beneficiation is performed in a water slurry, and the wet rock does not become airborne.

3.2 CONVEYING OF ROCK

Mined rock is normally moved by conveyor belts; some are open and others are closed for weather protection. Except in the relatively small plants in the hard rock areas of Utah and Wyoming, the high moisture content of the rock (from 10 to 15 percent by weight)[1] prevents emission of particulate matter. In arid or windy locations, weather-protected conveyors aid in emission control.

3.3 PHOSPHATE ROCK DRYING

The air stream from a rock dryer contains particulate and combustion products, including moisture. The temperatures at which the rock is dried are too low to drive off gaseous fluoride.[2] The effluent temperature ranges from 344° to 422°K (160° to 300°F) and the particulate loading is about 7 g/dry std. m^3 (3 gr/dscf).[3] The most commonly used control systems are various types of wet scrubbers, although two facilities use electrostatic precipitators. Table 3-1 and 3-1a give the operating and emission data for several collection systems, four of which are EPA tests (as indicated). Appendix A contains additional details of the EPA tests and the results of some sampling conducted by the industry.

3.3.1 Scrubbers

Scrubbers are by far the most common control device

Table 3-1. EMISSIONS FROM ROCK DRYERS EQUIPPED WITH VARIOUS TYPES OF CONTROL EQUIPMENT[4]

(S.I. UNITS)

Company	Location	Product rate Mg/h	Type of facility	Control device[a]	Stack gas flow rate dry std.m^3/s	Emissions			Remarks
						g/dry std.m^3	kg/h	g/Mg	
Agrico Chemical	Pierce, Fla.	907	UNK	IS	378	0.46	62.6	310	Production rate is total for four dryers; g/Mg and g/std. m^3 were calculated using total production, total gas flow and total emissions from all four units.
Beker Industries	Conda, Idaho	57	fluid bed	CS	12.7	0.16	7.3	130	
Borden Chemical	Plant City, Fla.	136	rotary	C	24.5	2.75	240	1750	
Brewster Phosphates	Bradley, Fla.	286	UNK	ESP	68.4	0.34	86.2	300	Production rate is for two dryers. Both are ducted to one ESP.
Conserv, Inc.	Nichols, Fla.	100	UNK	IS	12.7	0.34	15.9	160	
Gardinier, Inc.	Ft. Meade, Fla.	178	UNK	CS	36.3	0.32	41.7	235	
W.R. Grace & Co.	Bartow, Fla.	352	rotary fluid bed	IS&ESP IS&ESP	53[b]	0.02	4.5	12.5	Dryers are ducted to separate scrubbers. The combined scrubber outlet emissions follow one common duct to two parallel ESP's which have separate stacks. EPA Test.[d] Facility B
Hooker Chemical	Columbia, Tenn.	19	rotary	ES	8.5	0.37	11.3	600	This dryer operates at 477°K (exit gas temperature).
IMC Corporation	Noralyn, Fla.	499	UNK UNK	CS CS	73.2[b]	0.16 0.14	21.3 18.1	80	Production rate is total for two dryers.
IMC Corporation	Kingsford, Fla.	302	fluid bed	CS	31	0.09	10.9	40	EPA Test.[d] Facility A
Mobil Chemical	Nichols, Fla.	318 318	rotary rotary	VS VS	35 42	0.035 0.07	4.3 9.1	20 30	EPA Test.[d] Facility A EPA Test.[d] Facility A
Occidental Chemical	White Springs, Fla.	220	fluid bed	CS	43.9	0.[illegible]	10.9	50	
Rocky Mtn. Phosphates	Garrison, Mont.	4.5	rotary	VS	UNK	UNK	UNK	UNK	This dryer has not been tested. Dryer operates at 394-422°K (exit gas temperature).
J.R. Simplot	Conda, Idaho	136	rotary	C	10.4	0.53	19.1	140	This dryer operates at approximately 422°K (exit gas temperature) which is about 311°K hotter than Fla. dryers.
Stauffer Chemical	Leefe, Wyoming	50	rotary	TS	7.1	0.23	5.9	120	
Stauffer Chemical	Vernal, Utah	24 24	rotary rotary	C C	4.7 4.7	3.43 2.52	57.6 41.3	2450 1750	
Swift Chemical	Bartow, Fla.	161 240	rotary fluid bed	WS CS	26.4 35.9	0.92 0.14	86.6 17.7	535 75	
Texasgulf, Inc.	Aurora, NC	211	fluid bed	C	UNK	UNK	UNK	UNK	Emissions from this dryer have never been sampled.
USS Agri-Chem	Ft. Meade, Fla.	170	rotary	CS	UNK	UNK	UNK	UNK	

[a] LEGEND:

C = Cyclone
CS = Cyclonic scrubber
ES = Eductor scrubber
ESP = Electrostatic Precipitator
IS = Impingement scrubber
TS = Spray tower
VS = Venturi scrubber
WS = Wet scrubber (generic type not known)
UNK = Unknown

[b] Total for two dryers.

[c] These dryers averaged 252 and 100 Mg per hour production during the tests.

[d] See Appendix A for additional test results.

Table 3-1a. EMISSIONS FROM ROCK DRYERS EQUIPPED WITH VARIOUS TYPES OF CONTROL EQUIPMENT[4]

(ENGLISH UNITS)

Company	Location	Product rate, tons/h	Type of facility	Control device[a]	Stack gas flow rate		Particulate emissions		Remarks
					dscfm×10⁻³	gr/dscf	lb/h	lb/ton	
Agrico Chemical	Pierce, Fla.	1,080	UNK	IS	800	0.2	138	0.62	Production rate is total for four dryers; lb/ton and gr/scf were calculated using total production, total gas flow and total emissions from all four units.
Beker Industries	Conda, Idaho	63	fluid bed	CS	27	0.07	16	0.26	
Borden Chemical	Plant City, Fla.	150	rotary	C	52	1.2	530	3.5	
Brewster Phosphates	Bradley, Fla.	315	UNK	ESP	145	0.15	190	0.60	Production rate is for two dryers. Both are ducted to one ESP.
Conserv, Inc.	Nichols, Fla.	110	UNK	IS	27	0.15	35	0.32	
Gardinier, Inc.	Ft. Meade, Fla.	196	UNK	CS	77	0.14	92	0.47	
W.R. Grace & Co.	Bartow, Fla.	388	rotary fluid bed	IS&ESP IS&ESP	117[b]	0.01	9.7	0.025[c]	Dryers are ducted to separate scrubbers. The combined scrubber outlet emissions follow one common duct to two parallel ESP's which have separate stacks. EPA test[d] Facility B
Hooker Chemical	Columbia, Tenn.	21	rotary	ES	18	0.16	25	1.2	This dryer operates at 400°F (exit gas temperature).
IMC Corporation	Noralyn, Fla.	550	UNK UNK	CS CS	155[b]	0.07 0.06	67 60	0.16	Production rate is total for two dryers.
IMC Corporation	Kingsford, Fla.	333	fluid bed	CS	85	0.043	23.0	0.070	EPA Test.[d] Facility A
Mobil Chemical	Nichols, Fla.	243 350	rotary rotary	VS VS	75 78	0.015 0.03	9.5 20	0.039 0.06	EPA Test.[d] Facility A
Occidental Chemical	White Springs, Fla.	242	fluid bed	CS	89	0.033	24	0.10	EPA Test.[d] Facility A
Rocky Mtn. Phosphates	Garrison, Mont.	5	rotary	VS	UNK	UNK	UNK	UNK	This dryer has not been tested. Dryer operates at 250-300°F (exit gas temperature).
J.R. Simplot	Conda, Idaho	150	rotary	C	22	0.23	43	0.29	This dryer operates at approximately 300°F (exit gas temperature) which is about 100°F hotter than Fla. dryers.
Stauffer Chemical	Leefe, Wyoming	55	rotary	TS	15	0.10	13	0.24	
Stauffer Chemical	Vernal, Utah	26 26	rotary rotary	C C	10 10	1.5 1.1	127 91	4.9 3.5	
Swift Chemical	Bartow, Fla.	178 265	rotary fluid bed	WS CS	56 76	0.40 0.06	191 39	1.07 0.15	
Texasgulf, Inc.	Aurora, NC	233	fluid bed	C	UNK	UNK	UNK	UNK	Emissions from this dryer have never been sampled.
USS Agri-Chem	Ft. Meade, Fla.	187	rotary	CS	UNK	UNK	UNK	UNK	

[a] LEGEND:
C = Cyclone
CS = Cyclonic scrubber
ES = Eductor scrubber
ESP = Electrostatic Precipitator
IS = Impingement scrubber
TS = Spray tower
VS = Venturi scrubber
WS = Wet scrubber (generic type not known)
UNK = Unknown

[b] Total for two dryers.

[c] These dryers averaged 278 and 110 tons per hour production during the tests.

[d] See Appendix A for additional details.

used in the operation of phosphate rock dryers. Probably the most important design parameters for scrubbers are the amount of scrubber water used per unit volume of gas treated (liquid-to-gas ratio) and the intimacy of contact between the liquid and gas phases.[5] The latter parameter is generally related to the pressure drop across the scrubber.

Although wet collectors of various designs are used on rock dryer effluents, venturi, impingement, and cyclonic scrubbers are the most common. Venturi scrubbers generally achieve the highest emission reduction, usually at the expense of higher pressure drops and energy requirements. It is possible for a venturi scrubber to reduce emissions to as low as 0.071 g/dry std. m^3 (0.031 gr/dscf). An EPA test of the Occidental rock dryer venturi scrubber indicated an emission reduction from 4.48 to 0.034 g/dry std. m^3 (1.96 to 0.015 gr/dscf), representing over 99 percent collection efficiency.[6] This system operated at 4.5 kPa (18 in. WG) pressure drop and a liquid-to-gas ratio of 1.44 ℓ/actual m^3 (10.8 gpm/10^3 acfm).[6] Table 3-1 indicates other types of scrubbers can reduce emissions to a level of 0.07 to 0.46 g/dry std. m^3 (0.03 to 0.2 gr/dscf), and efficiencies of 90 to 95 percent are common.

The predicted collection efficiency of venturi scrubbers with a relatively low pressure drop of 3 kPa (12 in.

WG) is 80 to 99 percent for particulates 1 to 10 micrometers in diameter and 10 to 80 percent for those less than 1 micrometer. The predicted collection efficiency of scrubbers with a high pressure drop of 7.5 kPa (30 in. WG) may reach 96 to 99.9 and 80 to 96 percent, respectively, for particles in the same size ranges. These data were obtained by actual field tests on scrubber efficiency and particle size distribution by cascade impactors.[7]

Source test data on the performance of a venturi and a cyclonic wet scrubber are shown in Table 3-2. These data represent what might be classified as typical performance. Additional data are given in Appendix A for these and other EPA source tests.

3.3.2 Electrostatic Precipitators

Plate (electrode) voltage and the ratio of plate area to the volume of gas to be treated are the most important design parameters of an ESP. Particle resistivity and the ease of cleaning collected dust from the plates also affect ESP performance. Electrostatic precipitation is sometimes an economically attractive control technique in cases where fine dust particles predominate. Removing fine particles with a venturi scrubber requires relatively large power inputs (high pressure drops) to achieve the necessary efficiency. If power cost savings effected by the ESP exceed

Table 3-2. PERFORMANCE OF VENTURI AND CYCLONIC WET SCRUBBERS ON PHOSPHATE ROCK DRYERS[a]

	Venturi scrubber[b,9]		Cyclonic scrubber[c,7]	
	Inlet	Outlet	Inlet	Outlet
Exhaust volume, dry std. m^3/s (dscfm)	33.0 (70,000)	35.2 (74,600)	30.9 (65,500)	42.0 (89,000)
Temperature °K, (°F)	364 (195)	340 (153)	349 (168)	337 (148)
Moisture content, % v	26	26	26.5	26.5
Feed rate, Mg/h (tons/h)	220 (243)	220 (243)	220 (243)	220 (243)
Grain loading, g/dry std. m^3 (gr/dscf)	4.48 (1.96)	0.034 (0.015)	0.828 (0.362)	0.076 (0.033)
Mass emission, kg/h (lb/h)	533.4 (1176)	4.31 (9.51)	89.8 (198)	10.9 (24)
Emission factor, g/Mg feed (lb/ton)	2.420 (4.84)	19.5 (0.039)	400.0 (0.80)	47.0 (0.094)

[a] Additional performance test data are given in Appendix A.

[b] Operating at 4.5 kPa (18 in. WG) pressure drop and 1.44 ℓ/m^3 (10.8 gpm/10^3 acfm).

[c] Test operating data, such as pressure drop and liquid rate are not available.

the increased capital charges, this system can be more economical than the venturi scrubber.[8]

Two operators of phosphate rock dryers now use electrostatic precipitators. One has a conventional dry ESP to control emissions from two rotary dryers. The precipitator was designed for 95 percent efficiency, but typically operates at 93 percent.[10] The other uses a wet ESP designed at 150 $m^2/m^3 \cdot s^{-1}$ (0.75 ft^2 plate area/acfm). This unit controls emissions from two dryers operated in parallel, one a rotary design and the other a fluid bed. The control system at this plant is unusual in that the exhaust from each dryer is first cleaned by an impingement scrubber. The streams from both dryers are then combined and discharged through the ESP. Although the ESP was designed for an efficiency of 90 percent, it is probably operating at a higher efficiency because the gas flow rate is about 60 percent of design capacity. Simultaneous inlet and outlet tests have not been performed on the dryers; however, the operator reports inlet loadings to be 1.37 to 2.29 g/dry std. m^3 (0.6 to 1.0 gr/dscf) and EPA tests show outlet emissions to average about 0.023 g/dry std. m^3 (0.01 gr/dscf), or 98 to 99 percent efficiency.[11] Outlet test data for the wet ESP are shown in Table 3-3. Additional data on this unit can be found in Appendix A.

Table 3-3. ESP PERFORMANCE ON PHOSPHATE ROCK DRYER PARTICULATE EMISSIONS (OUTLET DATA)[11]

Exhaust volume[a]	52.86 dry std. m^3/s	112,000 dscfm
Temperature	316°K	110°F
Moisture content	8.9% v	8.9% v
Feed rate	353 Mg/h	389 tons/h
Outlet loading[b]	0.023 g/dry std. m^3	0.01 gr/dscf
Mass emission rate	4.42 kg/h	9.74 lb/h
Emission factor	12.5 g/Mg feed	0.025 lb/ton
ESP design	Wet-type	Wet-type
Plate area	4700 m^2	50,600 ft^2
Water rate	75.7 ℓ/s	1200 gpm
Estimated efficiency	98 to 99%	98 to 99%

[a] ESP preceded by impingement-type wet collectors, which are preceded by cyclone separators. ESP operated at 60% of design level.

[b] Inlet loading estimated at 1.37 to 2.29 g/dry std. m^3 (0.6 to 1.0 gr/dscf).

3.3.3 Fabric Filters

No fabric filters are known to be in use for phosphate rock dryer emission control. Many industry members believe that moisture condensation would be a major problem because water droplets could mix with the clay-like dust mat formed on the fabric media and cause a mud cake. Were this condition to occur, it would "blind" the bags. Furthermore, since the dust usually has no economic value, dry recovery for reprocessing is not an attractive incentive to operators.

To avoid condensation, a difference of 28°K (50°F) between the wet and dry bulb temperature is desirable.[12] This can be achieved by insulating all ductwork and the filter; however, the condensation potential still remains during process upsets, startup, and shutdown. Careful operating procedures and provision for an emergency bypass around the filter may prevent serious damage.

Overheating of the fabric media is not a problem, because the dryers operate at about 394°K (250°F) and the exhaust temperature is generally less than this. A temperature control system would ensure a temperature difference of at least 28°K (50°F) above the dew point and prevent overheating.

Contrary to the opinions expressed by industry experts, two major manufacturers, Wheelabrator-Frye and American Air

Filter, believe that fabric filters can be effective in this application. These companies state that successful operation of fabric filters are common in more difficult operations such as asphalt plants, cement plants, fertilizer dryers, and the clay industry.[8]

Under proper operating conditions, fabric filters generally exceed 99 percent efficiency and reduce emissions to less than 0.023 g/dry std. m^3 (0.01 gr/dscf). Similar processes for which fabric filters are used include clay and kaolin rotary and spray dryers. For this reason, fabric filters are considered a viable control technique along with wet scrubbers and ESP's, even though no direct evidence of their capability can be presented. (For more details on design and performance of fabric filters, consult Control Techniques for Particulate Air Pollutants.[12])

3.4 PHOSPHATE ROCK CALCINERS

As discussed in Chapter 2, calciners and dryers have similar emission characteristics. The gas stream leaving the commonly used fluid-bed calciner passes through a windbox, aftercooler, and cyclone separator prior to the point of final collection of the particulate emissions. Although calcining temperatures are 760° to 870°C (1400° to 1600°F), the effluent gas temperature is about the same as that of the dryer, about 392°K (250°F), because of the heat recovery that takes place in the aftercooler. Wet scrubbers are by far the most common control device, although an ESP is used by one company. Table 3-4 gives examples of various control devices and their measured emission reduction.

3.4.1 Wet Scrubbers

The wet scrubber achieves reasonable emission reduction at a nominal pressure drop and eliminates the danger of high temperature damage to the control system. Table 3-4 indicates particulate emission rate from calciners equipped with various types of wet collectors, including wet cyclones, impingement scrubbers, and venturi scrubbers. The venturi scrubber, which offers high efficiency at higher pressure drops, is the most frequently used control device.

One EPA test at Beker Industries indicated an outlet concentration of 0.073 g/dry std. m^3 (0.032 gr/dscf) on a venturi scrubber operating at a pressure drop of 3 kPa (12 in. WG) and a liquid recirculation rate of 2.4 ℓ/m^3 gas (18 gal/scf).[14] Table 3-5 gives additional performance data obtained from this source test.

The general range of emissions from calciners using other wet scrubbers is 0.114 to 0.69 g/dry std. m^3 (0.05 to 0.3 gr/dscf). Appendix A provides additional source test data.

Table 3-4. PARTICULATE EMISSIONS FROM PHOSPHATE ROCK CALCINERS[13]

(S.I. Units)

Company	Location	Production rate Mg/h	Type of calciner	Control device	Stack gas flow rate, wet std. m^3/s	Particulate emission rate, g/dry std m^3	kg/h	g/Mg
Beker Industries	Conda, ID	59	Fluid bed[a]	VS[b]	16.0	0.07	4.0	68.0
		63.5	Fluid bed	VS[c]	18.9	0.23	15.4	245
Mobil Chemical	Nichols, FL	45.5	Rotary	IS	26.0	0.11	11.3	250
J. R. Simplot	Pocatello, ID	31.8	Fluid bed	IS	11.8	0.69	29.0	900
		37.2	Fluid bed	CS	13.2	0.23	10.9	290
		49.9	Fluid bed	ESP	27.4	0.14	13.6	270
Stauffer Chemical	Leefe, WY	18.1	Fluid bed	C	8.0	3.52	102.1	5625
		18.1	Fluid bed	C	8.0	2.75	79.4	4375
		27.2	Fluid bed	C	13.7	1.44	71.7	2630
Texasgulf, Inc.	Aurora, NC	54.4	Fluid bed	VS[d]	25.0	0.09	7.4	135
		54.4	Fluid bed	VS[d]	25.0	0.09	7.4	135
		54.4	Fluid bed	VS[d]	25.0	0.09	7.4	135
		54.4	Fluid bed	VS[d]	25.0	0.09	7.4	135

LEGEND:

C = Cyclone
CS = Cyclonic Scrubber
ESP = Electrostatic Precipitator
IS = Impingement Scrubber
VS = Venturi Scrubber

[a] EPA Test Facility C, Appendix A.

[b] Scrubber pressure drop is 2 kPa.

[c] Scrubber pressure drop is 3 kPa.

[d] Scrubber pressure drop is 5 kPa.

Table 3-4a. PARTICULATE EMISSIONS FROM PHOSPHATE ROCK CALCINERS[13]

(ENGLISH UNITS)

Company	Location	Production rate tons/h	Type of calciner	Control device[a]	Stack gas flow rate, scfm x 10^{-3}	Particulate emission rate, gr/dscf	lb/h	lb/ton
Beker Industries	Conda, ID	65	Fluid bed[a]	VS[b]	32.8	0.032	8.8	0.136
		70	Fluid bed	VS[c]	40	0.10	34	0.49
Mobil Chemical	Nichols, FL	50	Rotary	IS	55	0.05	25	0.5
J. R. Simplot	Pocatello, ID	35	Fluid bed	IS	25	0.3	64	1.8
		41	Fluid bed	CS	28	0.1	24	0.58
		55	Fluid bed	ESP	58	0.06	30	0.54
Stauffer Chemical	Leefe, WY	20	Fluid bed	C	17	1.54	225	11.25
		20	Fluid bed	C	17	1.20	175	8.75
		30	Fluid bed	C	29	0.63	158	5.26
Texasgulf, Inc.	Aurora, NC	60	Fluid bed	VS[d]	53	0.04	16.4	0.27
		60	Fluid bed	VS[d]	53	0.04	16.4	0.27
		60	Fluid bed	VS[d]	53	0.04	16.4	0.27
		60	Fluid bed	VS[d]	53	0.04	16.4	0.27

[a] EPA Test Facility C, Appendix A.

[b] Scrubber pressure drop is 8 in. WG.

[c] Scrubber pressure drop is 12 in. WG.

[d] Scrubber pressure drop is 20 in. WG.

LEGEND:

C	= Cyclone
CS	= Cyclonic Scrubber
ESP	= Electrostatic Precipitator
IS	= Impingement Scrubber
VS	= Venturi Scrubber

Table 3-5. PERFORMANCE OF VENTURI SCRUBBER ON PHOSPHATE ROCK CALCINER (OUTLET)[14,a]

Exhaust volume	15.48 dry std. m^3/s	32,800 dscfm
Temperature	329°K	132°F
Moisture content	6.4% v	6.4% v
Feed rate	58.8 Mg/h	64.8 tons/h
Grain loading	0.073 g/dry std. m^3	0.032 gr/dscf
Mass emissions	4.0 kg/h	8.8 lb/h
Emission factor	68.01 g/Mg feed	0.136 lb/ton
Control device	ARCO venturi scrubber	ARCO venturi scrubber
Pressure drop	3 kPa	12 in. WG
Liquid rate	37.9 ℓ/s	600 gpm

[a] EPA Test Facility C, Appendix A.

3.4.2 Electrostatic Precipitators

Electrostatic precipitators can be an economical control technique. For example, when calciner dusts contain a high fraction of very fine particles, venturi scrubbers require a high power input to achieve a satisfactory collection efficiency. The power cost savings effected by using an ESP to collect these dusts could offset the increased capital cost over that of a venturi scrubber.[9] This is shown in the cost analyses in Chapter 4.

A calciner at one operation has a 1605 m^2 (17,280 ft^2) two-stage, dry ESP, which operates at 33.47 actual m^3/s (70,900 acfm) at 419°K (295°F) D.B. and 347°K (165°F) W.B. This corresponds to a volume to plate area ratio of 0.015 m^3/s per m^2 (2.9 scfm/ft^2). The company reports inlet and outlet loading averages of 10.75 g/dry std. m^3 (4.7 gr/dscf) and 0.022 g/dry std. m^3 (0.0094 gr/dscf), corresponding to an overall efficiency of 99.8 percent. Tests performed by the operators using the WP-50 Test Methods show an outlet loading of 0.14 g/dry std. m^3 (0.06 gr/dscf) at a 99 percent efficiency.[15] ESP maintenance at this facility is minimal, mostly routine cleanout and inspection.

3.4.3 Fabric Filters

Problems associated with using fabric filters on calciner exhausts are similar to those described for the dryer operation (Section 3.3.3). No fabric filters are now being used on phosphate rock calciners. Producers commonly cite high exhaust gas temperature as the major difficulty expected with this kind of control device. During normal operation, the gases are cool enough not to endanger the fabric material or the baghouse collector (394°K [250°F]) During periods of operational upsets, however, temperatures can approach 644°K (700°F). Upsets occur frequently during start-up and shutdown and sometimes during normal operation because of equipment or power failures. The high temperatures during these periods could result in excessive maintenance expenses, primarily for bag replacements.[16]

As in the dryer application, moisture content (up to 25% v) poses a potential problem of condensation on the fabric during normally low exhaust temperatures [less than 366°K (200°F)]. With higher temperatures, condensation is less troublesome but fabric overheating becomes a problem.

The installation of cooling equipment such as heat exchangers and water sprays can maintain safe temperature levels for fabric filters on calciners. On similar operations where fabric filtration is used, such as clay and kaolin rotary and spray dryers, particulate emissions are controlled to less than 0.023 g/dry std. m^3 (0.01 gr/dscf) at an efficiency of more than 99 percent. There is no reason why this technology cannot be transferred to phosphate calciners.

Dust from calcining operations has little economic value; therefore dust recycling does not offer an economic advantage.

3.5 GRINDING

Dried and calcined rock is ground before it is used for the manufacture of fertilizers (as described in Chapter 2). The grinding or milling circuit operates under slightly negative pressure to prevent the escape of gases containing ground rock dust. The system is not airtight; hence the air that is drawn into the system must be vented. This vent stream usually discharges through a fabric filter or, sometimes, a wet scrubber. Grinder exhaust volumes usually range from 0.0312 to 0.0833 dry std. $m^3 \cdot s^{-1}$ per Mg^3 h^{-1} (60 to 160 dscfm/TPH) at 322°K (120°F) and contain 4.6 to 11.4 g/dry std. m^3 (2 to 5 gr/dscf) particulate matter. The grinding operation is purely mechanical and poses no threat of fluoride evolution other than as a part of the particulate. Table 3-6 presents performance data for wet scrubbers and fabric filters in the control of emissions from grinding operations. Electrostatic precipitators are not used for this operation.

Table 3-6. PARTICULATE EMISSIONS FROM PHOSPHATE ROCK GRINDERS[18]

(S.I. UNITS)

Company	Location	Production rate Mg/h	Number of mills	Type of mill	Control Device[a]		Stack gas flow rate std. m^3/s	Particulate emissions			Remarks
					number	type		g/std. m^3	kg/h	g/Mg	
Agrico Chemical	Pierce, Florida	157	6	Roller	6	BH	0.19	0.12- 0.46	6.8	45	
Beker Industries	Conda, Idaho	74 68	1 2	Ball Ball	1 2	BH BH	1.8	0.0048 NR	0.036 NR	0.45 NR	Emissions from two of the three ball mills have never been sampled. The plant used EPA Method 5 to sample the third mill. Facility G in Appendix A.
Brewster Phosphates	Bradley, Florida	NR	2	Roller	1	BH	3.4	0.0083	0.10	NR	
Farmland Industries	Bartow Florida	100	1	Ball	1	BH	2.1	0.018	0.45	4.5	
Gardinier, Inc.	Tampa, Florida	213	1 5	Roller Roller & ball	1 5	IS BH	4.5 5.8	0.25 0.037- 0.16	4.3 5.0	40 NR	Production rate and g/Mg emissions are for all six mills.
W.R. Grace and Co.	Bartow, Florida	41 141	3 2	Roller Ball	1 1	WS	7.7 5.8	0.14 0.18	3.2 3.6	75 25	
IMC Corporation	Noralyn, Florida	218 32	7 1	Roller & ball	5 1	BH BH	4.7 1.28	0.18 0.015	12.3 0.068	55 2.1	EPA Test Facility G, Appendix A.
IMC Corporation	Kingsford, Florida	100	3	Roller	2	VS	9.9	0.39	14.5	145	
Mobil Chemical	Nichols, Florida	190	4	Roller	2	WS	3.8	0.46	5.0	22	
Occidental Chemical	White Springs, Florida	116	1	Ball	1	BH	6.42	0.024	0.5	4.4	EPA Test Facility D, Appendix A.
Royster Company	Mulberry, Florida	70	2	Roller & ball	1	BH	3.9	0.0046	0.048	0.65	One baghouse cleans emissions from both mills. Emission tests performed using WP-50 method with slight variations. Facility F in Appendix A.
J.R. Simplot	Pocatello, Idaho	91	6	Roller	3	BH	16.1	0.007- 0.016	0.06	6.5	
Stauffer Chemical	Leefe, Wyoming	36	3	Roller	3	BH		NR	NR	NR	Emissions from the mills have never been sampled.
Swift Chemical	Bartow, Florida	41	3	Roller	3	WS	2.8	0.14- 0.35	2.9	65	
Texasgulf, Inc.	Aurora, N.C.	136	2	Ball	2	BH	11.3	0.35	14.0	105	
USS Agri-Chem	Bartow, Florida	41	3	Roller	5	BH	4.3	0.20	3.0	74	
USS Agri-Chem	Ft. Meade, Florida	68	4	Roller	5	BH	4.6	0.005	0.06	1.0	

[a]LEGEND:
BH = Baghouse
IS = Impingement scrubber
VS = Venturi scrubber
WS = Wet scrubber (Generic type not known)
NR = Not reported

Table 3-6a. PARTICULATE EMISSIONS FROM PHOSPHATE ROCK GRINDERS[18]

(ENGLISH UNITS)

Company	Location	Production rate, tons/h	Number of mills	Type of mill	Control Device number	Control Device type	Stack gas flow rate acfm×10⁻³	Particulate emissions gr/scf	Particulate emissions lb/h	Particulate emissions lb/ton	Remarks
Agrico Chemical	Pierce, Florida	173	6	Roller	6	BH	0.4	0.05-0.2	15	0.09	
Beker Industries	Conda, Idaho	81 75	1 2	Ball Ball	1 2	BH BH	4.1	0.002 NR	0.08 NR	0.0009 NR	Emissions from two of the three ball mills have never been sampled. The plant used EPA Method 5 to sample the third mill. Facility G in Appendix A.
Brewster Phosphates	Bradley, Florida	NR	2	Roller	1	BH	7.1	0.0036	0.22	NR	
Farmland Industries	Bartow Florida	110	1	Ball	1	BH	4.4	0.008	1.0	0.009	
Gardinier, Inc.	Tampa, Florida	235	1 5	Roller Roller & ball	1 5	IS BH	9.6 12.3	0.11 0.016-0.070	9.4 11.0	0.08	Production rate and lb/ton emissions are for all six mills.
W.R. Grace and Co.	Bartow, Florida	45 155	3 2	Roller Ball	1 1	WS	16.3 12.2	0.06 0.08	7.0 8.0	0.15 0.05	
IMC Corporation	Noralyn, Florida	240 35	7 1	Roller & ball	5 1	WS BH	10.0 2.7	0.08 0.0065	27.0 0.15	0.11 0.0042	Facility E in Appendix A.
IMC Corporation	Kingsford, Florida	110	3	Roller	2	VS	21.0	0.17	32	0.29	
Mobil Chemical	Nichols, Florida	209	4	Roller	2	WS	8.0	0.2	11	0.044	
Occidental Chemical	White Springs, Florida	124	1	Ball	1	BH	13.6	0.010	1.10	0.009	
Royster Company	Mulberry, Florida	78	2	Roller & ball	1	BH	6.3	0.002	0.103	0.0013	One baghouse cleans emissions from both mills. Emission tests performed using MP-50 method with slight variations. Facility F in Appendix A.
J.R. Simplot	Pocatello, Idaho	100	6	Roller	3	BH	34.0	0.003-0.007	1.33	0.013	
Stauffer Chemical	Leefe, Wyoming	40	3	Roller	3	BH	NR	NR	NR	NR	Emissions from the mills have never been sampled.
Swift Chemical	Bartow, Florida	45	3	Roller	3	WS	6.0	0.06-0.15	6.4	0.13	
Texasgulf, Inc.	Aurora, N.C.	150	2	Ball	2	BH	24.0	0.15	30.9	0.21	
USS Agri-Chem	Bartow, Florida	45	3	Roller	5	BH	9.1	0.086	6.6	0.147	
USS Agri-Chem	Ft. Meade, Florida	75	4	Roller	5	BH	9.8	0.002	0.13	0.002	

[a] LEGEND: BH = Baghouse; IS = Impingement scrubber; VS = Venturi scrubber; WS = Wet scrubber (Generic type not known); NR = Not reported

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3.5.1 Fabric Filters

Fabric filters are normally used to control emissions from grinders, probably because the dust collected by a fabric filter can be added directly to the product and thereby increase yields. Also, the low moisture content of 5 percent or less and low temperatures of 310 to 339°K (100 to 150°F) make fabric filtration technically and economically feasible. In some plants, however, the moisture content of the ground rock dust collected by fabric filters causes much difficulty. At these plants, wet collectors are usually chosen for control. However, as discussed in Section 3.3.3, the problem of moisture condensation in fabric filters can be overcome. Refer again to Table 3-6 for typical emission rates for grinders equipped with fabric filters. Table 3-7 indicates typical performance of fabric filters during EPA tests. Appendix A presents details of these and other tests. Operators report no variation in emissions from fabric filters as a result of such factors as fineness of grinding, type of rock, ambient conditions, or any other equipment or process variable that can be controlled.[17]

Pulsed-air fabric filters designed with a filter velocity of 2 to 2.5 cm/s (4 to 5 fpm) are common. Continuous-shaker fabric filters with a filter velocity of 1 to 1.5 cm/s (2 to 3 fpm) could be used.

Table 3-7. FABRIC FILTER PERFORMANCE ON PHOSPHATE ROCK GRINDER EMISSIONS

Parameter	System 1[a,14]		System 2[b,19]	
	Inlet	Outlet	Inlet	Outlet
Exhaust volume, dry std. m^3/s (dscfm)	1.75 (3700)	1.89 (4000)	1.42 (3000)	1.27 (2700)
Temperature, °K (°F)	380 (224)	386 (235)	367 (202)	345 (161)
Moisture content, % v	2.9	0	6	6
Feed rate, Mg/h (tons/h)	73 (81)	73 (81)	31.3 (34.5)	31.3 (34.5)
Grain loading, g/dry std. m^3 (gr/dscf)	8.47 (3.7)	0.0048 (0.0021)	7.44 (3.25)	0.015 (0.0065)
Mass emissions, kg/h (lb/h)	53.5 (118)	0.036 (0.08)	37.6 (83)	0.068 (0.150)
Emission factor, g/Mg (lb/ton) feed	730 (1.46)	0.45 (0.0009)	1200 (2.4)	2.10 (0.0042)

[a] Pulse-air fabric filter designed at filter velocity of 2.5 cm/s (5 fpm); Beker Industries, Facility G in Appendix A

[b] Fabric filter designed at filter velocity of 2 cm/s (4 fpm); IMC Corp. Noralyn, Florida; Facility E in Appendix A.

The information in Tables 3-6 and 3-7 and EPA test data given in Appendix A indicate that fabric filters can generally achieve emission levels below 0.03 g/dry std. m^3 (0.013 gr/dscf) and maintain efficiencies greater than 99 percent. Well-designed units can achieve even greater than 99.9 percent efficiency.

3.5.2 Scrubbers

Scrubbers are sometimes used to control emissions from grinders; they are usually low-energy venturi or impingement scrubbers that operate at 2 to 2.5 kPa (8-10 in. WG) pressure drop. Based on data in Table 3-6 and Appendix A, emissions from these devices typically range from 0.137 to 0.458 g/dry std. m^3 (0.06 to 0.20 gr/dscf), depending on the pressure drop. Such devices can be designed to meet typical state emission requirements.

For performance data for the various types of scrubbers in operation, refer again to Table 3-6. For more information on scrubber design and operation, consult Air Pollution Control Techniques for Particulate Air Pollutants (AP-51).[12]

3.6 MATERIALS HANDLING AND STORAGE

Emissions from materials handling systems are difficult to quantify because many different systems are employed to convey rock and because fugitive emissions comprise a large part of the emission potential. Materials handling systems range from front-end loaders and other manual conveyances to automated pneumatic systems. From an emissions standpoint, the basic differences in the systems are the precautions taken to prevent the dust from becoming airborne and the ease with which the dust can be captured.

The most common type of transfer system for unground rock consists of conveyor belts and bucket elevators. In order to minimize fugitive emissions caused by ambient air currents, conveyor belts for moving dried rock are usually covered and sometimes enclosed. The transfer point where the material falls by gravity from the conveyor belt is the major source of emissions from this type of system. Hot rock or ambient winds can also cause small amounts of fugitive dust at points along the housed enclosure. Although transfer points are sometimes hooded and evacuated to minimize fugitive emissions, all of those observed by EPA in the phosphate rock industry had visible emissions. Some conveyors used for similar applications in the crushed-stone industry are able to control transfer points to the extent that no emissions are visible.[20]

Bucket elevators are usually enclosed and evacuated to a control device; otherwise they would generate substantial amounts of dust.

Rock that has been ground is normally conveyed in totally enclosed systems, such as those described in Chapter 2. These systems limit fugitive emissions very effectively, since discharge points of material and of particulate-laden air are well defined and easily controlled by fabric filters. In essentially all cases, proper maintenance of the transfer system and its control device ensures effective control of particulate emissions. Because the pneumatic systems operate under positive pressure, a leak in the transfer system itself requires immediate attention by plant personnel to minimize product loss.

The usual procedure is to store both ground and unground dry rock in enclosed bins or silos that are vented to the atmosphere. Emissions from the vents are frequently controlled by fabric filters. On pneumatic ground-rock-handling systems, this is the same fabric filter that controls emissions from the transfer system. The collected dust is returned to the silo.

The control of air pollution must be a priority item in the design of new materials-handling systems; retrofitting is frequently costly and difficult because of space limitations and often results in a less efficient system. This is discussed in detail in Section 3.8 and Chapter 4.

3.7 WET GRINDING

The recent move toward wet grinding of rock for the manufacture of wet-process phosphoric acid (WPPA) holds the most promise for emission control from dryers and calciners. The rock is ground in a water slurry, then added to the WPPA reaction tanks without drying. This technique has not been practiced previously because the water entrained with the ground rock required either the use of a stronger acid in the WPPA reaction or removal by evaporation to maintain the 54 percent P_2O_5 strength needed for production of fertilizer. Historically, 93 percent sulfuric acid has been diluted to 58 percent for the WPPA reaction to permit removal of the heat of dilution prior to its addition to the reactor. If added to the reactor at 93 percent strength, the heat of dilution coupled with the heat of reaction would exceed the capacity of the vacuum flash cooler used for temperature control. Also, it was widely accepted that the higher temperatures would result in formation of smaller crystals of waste gypsum, which would complicate the separation of product acid from waste gypsum.

Two companies overcame their reservations about the wet grinding process and designed larger flash coolers on the reactors to remove the heat of dilution. They found no significant difference in the crystal size of the gypsum.[21]

The products from the reactor are fed to the evaporators at 28 to 32 percent P_2O_5 acid, as in the conventional WPPA process.

One possible problem created by wet grinding is increased water treatment costs. The EPA's effluent water regulations call for zero discharge by 1980. About 460 ℓ of water per Mg of throughput (110 gal/ton) is generated and requires treatment at one plant.[21] The potential savings resulting from elimination of the energy-intensive phosphate-rock dryer, its air pollution control system, and the air pollution controls for the grinder is, however, a strong incentive to the operator.

Plant management contends that the major driving force regarding this process is not improved technology, but increasingly expensive fuel costs and stringent air emission regulations.[21] It is now less expensive to treat the wet rock than to contend with high energy costs and stringent air regulations.

The impact of the wet grinding process could be far-reaching because about 70 percent of all phosphate rock is ultimately used to produce fertilizer,[22] and 85 percent of the rock used for fertilizer must first be converted to phosphoric acid.[23] Present indications are that the trend will be toward wet grinding,[24] and the growth rate for phosphate rock dryers will become negligible. Of course, some dry rock will still be required unless ways are found to introduce wet ground rock into processes other than WPPA. Much of this need may well be filled by the capacity of existing dryers, thereby precluding the construction of new ones. The need for emission controls on phosphate rock grinders may be diminished, but it will not be eliminated because the calcination process is likely to continue at its current rate of growth and calcined rock must be ground.

3.8 RETROFITTED CONTROL SYSTEMS

It is more difficult to retrofit an emission control system in an existing facility than to incorporate it into a new plant design. Installation of control systems on existing processes is more difficult for the following major reasons:

Plant age - Installation of control equipment may require structural modifications to the plant and/or process alterations. In some cases, however, it may be feasible to locate control equipment on the ground adjacent to the phosphate rock processes.

Available space - Installation may require extensive steel supports and/or site preparation. Control equipment may have to be custom-designed to meet space allocations. Longer duct runs are usually necessary.

Utilities - Electrical, water supply, and waste removal and disposal facilities may require expansion. These will not generally be a problem in this industry.

Production shutdown - Loss of production during retrofit adds to the initial cost of installing control equipment. Long-term shutdowns due to installation of control equipment are not expected in the phosphate rock industry.

Labor - Higher labor costs result from the additional labor usually required because of increased installation time and from overtime wages paid during normal shutdown periods.

Engineering - Engineering time is required to integrate control systems into the existing operation.

The major restriction encountered when retrofitting air pollution control equipment in the phosphate rock processing industry is limited space. The arrangement of existing process equipment may necessitate locating the new control device and some auxiliary equipment, such as fans, pumps, etc., on a site 15 to 30 meters (50 to 100 feet) or more from the emissions source.

In the phosphate rock industry medium-energy impingement or cyclonic wet collectors are often replaced with venturi scrubbers or other high-efficiency wet collectors. Such replacement may require installation of a new fan. If a wet collector is replaced by a fabric filter or electrostatic precipitator, considerably more space is necessary, and rearrangement of existing ductwork and extension of new ductwork is sometimes required to allow adequate space for the control device.

Because most calcining, drying, and grinding operations are already equipped with some type of emission control system, the retrofitting of a control system to achieve higher collection efficiencies normally entails the removal of the existing control device and the use of some of the auxiliary equipment and ductwork. The use of existing fans depends on the fan capacity specified for the system pressure drop and exhaust flow rate. Existing ductwork dimensions must be adequate to incorporate into the new system. Remaining equipment life must also be considered in reusing this equipment.

One company completely replaced a fabric filter on a grinding operation, using existing ductwork and supports.[25] In this case, the same location was adequate for the new fabric filter and no new ductwork, foundations, supports, or fan was required. A spokesman for another company stated that there are no unique problems associated with retrofitting, although location, space, and structural limitations are typical.[26]

A Florida producer retrofitted an ESP on the drying operation. The ESP was installed downstream from two existing scrubbers. Because placing the ESP near the drying operation would have crowded the area around the grinding mill, it had to be situated over service railroad tracks, causing the use of the railroad tracks to be discontinued. Because the distance between the drying operation and the ESP was 24 to 30 m (80 to 100 ft) greater than it would have been at a new plant, additional ductwork was required.[27]

At the same facility a three-stage scrubbing unit was retrofitted to replace an old wet collector on the dryer operation. The new unit had to be situated at an elevation of 30 m (50 ft) above ground level in a structure built in 1953 in order to utilize the existing water drainage system. The major problem encountered was that of the excess weight on the foundation of the building (the structural steel was sufficient to handle the weight). Grout and concrete were pumped under the foundation to strengthen it.[27]

At another operation in Florida, scrubbers were added to an existing drying facility. The scrubbers were installed on a foundation at ground level, and ducting was connected to an elevated cyclone system that served as the only control device for the dryer emissions. This retrofitted system was similar to a system installed on a new plant because no space limitations, long duct runs, or other problems were encountered during the installation.[28]

Conversion to wet grinding can be feasible at plants that produce phosphate for wet process phosphoric acid plants, even though replacement of dry grinding with wet grinding can be a difficult conversion. Such conversion lowers grinder capacity, and some problems have been encountered with controlling the moisture content of the product. It is necessary to remove air conveying systems and install piping and pumping systems to facilitate the transport of the product slurry.[29]

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4.0 COSTS OF APPLYING CONTROL TECHNOLOGY

4.1 INTRODUCTION

4.1.1 Purpose

This section presents capital, operating, and annualized cost estimates for the control of particulate emissions from selected phosphate drying, calcining, and wet and dry grinding operations. The costs presented herein are not detailed estimates from actual system designs, but rather predesign cost estimates, accurate to within ± 20 to 30 percent for the model plants chosen, which can serve as a guide for control officials and industry personnel. All costs have been escalated to reflect fourth quarter 1977 prices by using the Chemical Engineering Index (212) for plant construction costs. The costing methodology is also presented to allow cost estimations at specific sites where design and operating parameters are considerably different from those assumed herein.

4.1.2 Scope

Process and emission control systems for which costs are presented are given in Table 4-1. Annualized, direct operating, and capital costs are determined for three levels of control: two state regulations (SIP_1 and SIP_2), and an alternative emission level (AEL). Appendix B contains an explanation of SIP and AEL controls and includes plots of allowable emissions versus process weight rate.

Table 4-1. PROCESS/CONTROL SYSTEMS CONSIDERED FOR COST ANALYSES

	Control system		
Process	Venturi scrubber	Fabric filter	Electrostatic precipitator
Drying	x	x	x
Calcining	x	x	x
Grinding	x	x	

The wet grinding process is one alternative control method gaining wide recognition throughout the industry as a replacement for the drying and grinding operation (see Section 2.5). This method of eliminating emissions is feasible only when the phosphate rock being produced is used for the raw material in the manufacture of wet process phosphoric acid (WPPA). The costs for replacing conventional grinding equipment with wet grinding are also discussed.

Typical capacities were selected for each process to represent small, medium, and large production rates as shown in Table 4-2. All costs are developed from the model processes.

Table 4-2. PRODUCTION CAPACITIES OF SELECTED MODEL PROCESSES

Process	Capacity, Mg/h (tons/h)		
	Small	Medium	Large
Drying	45 (50)	181 (200)	272 (300)
Calcining	45 (50)	41 (45)	64 (70)
Dry grinding	45 (50)	91 (100)	136 (150)
Wet grinding	45 (50)	91 (100)	136 (150)

In addition, costs are presented as a function of the exhaust flow rate for each process. Since exhaust flow rates per unit production rate vary significantly from one operation to the next, control costs for a given process and control system are expressed as a function of exhaust flow rate instead of production rate. These estimates based on flow rate are likely to represent the actual costs within a 20 to 30 percent range since exhaust gas characteristics are based upon actual field testing.

The capital and annual costs for installing control equipment on existing plants only (retrofitted systems) are given in this document. Retrofitted systems may be significantly higher or lower in total cost than systems installed on new plants, depending on site-specific parameters such as available space, foundation requirements, duct location, etc. Retrofitted control systems are discussed in more detail later in this section.

The capital and annualized costs developed by the analyses described in this chapter are compared to actual costs in the industry. Generally, most estimated and actual costs compared reasonably well.

As discussed in Section 3, costs are not presented for electrostatic precipitators on grinding operations since they are not used in the industry. Calcining and drying operations normally require a product recovery cyclone, which could be considered process equipment; therefore the control costs do not include these recovery cyclones. Fabric filters used on ground rock transport systems are considered product recovery equipment; therefore, no costs are presented.

4.1.3 Use of Model Processes and Plants

Usually, each of the multiple-parallel processes, i.e. three 91.0 Mg/h (100 tons/h) dryers, is controlled by a separate system. To estimate the total control cost for an entire model plant, the cost for a combination of the model processes must be added.

The total number of possible process configurations for an entire plant is well over 100, with two to three control options per process. Possible process/control configurations are numerous for one specific plant size, and none is typical. For this reason, total model plant costs are not developed. This chapter is presented so that costs may be estimated for individual processes with a known exhaust flow rate. By this approach, error in cost estimating will be minimized.

4.1.4 Bases for Capital Cost Estimates

Capital costs developed in this chapter include the total cost of buying and installing equipment items such as control devices, ductwork (including flanges, expansion joints, and dampers), fans, stacks, pumps, and tanks. Research and development costs and production losses during construction and start-up are not included. No cost estimates are included for additional solid waste or wastewater treatment and disposal facilities since they are generally unnecessary. Sections 5.3 and 5.4 will show that increases in wastewater and solid waste volumes are insignificant. Furthermore, treatment facilities normally are available on site and do not need expansion to handle the increase in waste treatment and disposal.

Purchase Costs - Cost information is primarily from reliable vendors and cost handbooks. Information sources for purchase costs of selected equipment are given in Table 4-3. Field data obtained by EPA and/or engineering judgment determined equipment specifications to achieve a desired system performance.

Direct Costs - Installed costs are estimated by multiplying the unit price for a given equipment item (obtained from a vendor or other reliable source) by the direct cost factor shown in Table 4-4. The final cost includes items such as instrumentation, piping, electrical, foundation, structures, sitework, insulation, painting, and labor required for installation.

Table 4-3. INFORMATION SOURCES FOR PURCHASE COSTS OF SELECTED EQUIPMENT

Fabric filters	American Air Filter Flex-Kleen, Inc. Standard-Havens Fisher-Klostermann Sly Equipment Mfg. Air-Pro., Inc.
Venturi Scrubbers	Sly Equipment Mfg. Fisher-Klostermann Gard Cost Manual[6]
Electrostatic precipitators	Members of Industrial Gas Cleaning Institute[11]
Fan systems	Twin City Fans Air-Pro., Inc. Buffalo-Forge PEDCo Files
Ductwork	Means Cost Data PEDCo Files
Pump systems	Ingersoll-Rand
Tanks	Chemical Engineering
Temperature control loops	Leeds and Northrup 1976-77 Catalogue
Insulation	Kramig Co., Cincinnati
Stacks	Gard Cost Manual[6]
Dry and wet grinding systems	Kennedy Von Saun

Table 4-4. DIRECT COST COMPONENTS USED IN COMPUTING INSTALLED COSTS[1,2,3]

Base equipment	Direct cost factor[a]
Fabric filters	2
Electrostatic precipitators	2
Venturi scrubbers	3
Hold tanks	2
Ductwork	2.6
Fan systems	2.5
Pump systems	3.5
Stacks	1.5

Components included in direct costs are equipment, instrumentation, piping, electrical, foundations, structures, sitework, insulation, and painting.

[a] Multiply direct cost factor by base equipment price to obtain material and labor costs for direct field erection costs. Installation factors were obtained from Chemical Engineering Magazine, Perry's Handbook, IGCI, and PEDCo Environmental.

Indirect Costs - Table 4-5 shows the indirect cost components as a percent of total direct costs. Total indirect costs amount to about 36 percent of the total direct costs and include engineering, field labor and expenses, contractor's fees, freight, offsite, spares, taxes, and shakedown.

Table 4-5. INDIRECT COST COMPONENTS USED IN COMPUTING INSTALLED COSTS[1,2,3]

Item	Percent of direct cost
Engineering	10
Field labor and expenses	10
Contractor's fee	5
Freight	1.3
Offsite	3
Spares	0.5
Taxes	1.5
Shakedown	5
Total indirect costs[a]	36.3

[a] Production losses and interest during construction and research and development costs are not included.

Contingencies - To determine the total capital cost, the sum of the direct and indirect cost is multiplied by a contingency factor. Contingencies include unforeseen costs attributable to omissions and field changes, inclement weather, strikes, delayed shipments, material shortages, price increases, breakage, and additional material requirements. The contingencies are generally between 10 and 30 percent of the indirect and direct costs. Therefore, a contingency cost of 20 percent of the total direct and indirect cost (contingency factor of 1.2) is assumed to be typical.

Retrofit Factors - To obtain capital costs for an existing plant, the total capital costs for a new plant are multiplied by a retrofit factor. Retrofit factors can only be determined for site-specific cases where actual plant layouts, plot plans, building designs, and other information are available. A meaningful retrofit factor cannot be developed on a generalized basis.

To illustrate, consider a plant in which the existing ductwork, fan, and stack are suitable for use in the proposed control system. The overall costs would be lower than for a new plant installation. One company completely replaced a fabric filter and estimated that the total cost could be up to 40 percent lower, using existing ductwork and supports, than a completely new installation.[4] This situation would be common in the phosphate rock industry since some degree of dust control has already been implemented by most plants.

In contrast, consider a process that requires a completely new control system (including fan, ductwork, and stack), structural modifications, removal of existing controls, extra long duct runs, and additional labor for site preparation. The overall capital costs would be considerably higher than for a new plant installation. One equipment manufacturer has estimated retrofitted costs to be an additional 10 to 15 percent of the capital costs for a new plant installation.[5] These costs could be as high as 50 percent of the total capital. The retrofit factor is assumed to be 1.2 for the purposes of this cost analysis and represents the typical additional costs for a completely new control system retrofitted on an existing plant.

Total Installed Costs - The total installed costs for retrofitted systems on existing processes are determined by multiplying the individual equipment costs by the respective direct cost factor (Table 4-4). The summation of the direct equipment costs are multiplied by an indirect cost factor of 1.363 (Table 4-5), a contingency factor of 1.2, and a retrofit factor of 1.2. Collectively, the total direct cost can be multiplied by 1.96 to account for indirect, retrofit, and contingency costs.

4.1.5 Bases for Annualized Cost Estimates

Annualized costs developed in this chapter include utilities, operating labor, maintenance, and fixed costs (including annualized capital charges). Product recovery credits are included for the grinder fabric filter option only; dust recovered from other processes has little value and is usually discarded in the tailings pond. Costs are not included for operation of sludge or wastewater treatment and disposal equipment since these facilities are normally available and no significant increases in waste handling requirements are expected. The annualized costs do not include return-on-investment and production losses resulting from breakdown and maintenance of control equipment. Adjustments for geographical area and other site-specific factors can also be made where necessary.[6]

Table 4-6 gives the cost factors used in computing total annualized costs. When site-specific information is available, it can be substituted for the assumed values shown.

4.2 DRYING

4.2.1 Model Process Parameters

Three typical dryer capacities were selected for the basis of the control cost analysis shown in Table 4-7. For multiple parellel configurations, separate control systems are generally installed. For the purposes of estimating the annual operating costs, these systems are assumed to operate 80 percent of the time, or about 7000 hours per year.

Table 4-6. COST COMPONENTS USED IN COMPUTING ANNUALIZED COSTS

I.	Operating factor	80%[a]
II.	Utilities	
	Electricity	$0.03/kWh
	Water	$0.25/1000 gal
III.	Operating labor[6]	$10/man-hour
	Direct labor	0.1 to 0.3 man-hour/h operation[b]
	Supervision[6]	15% Direct
IV.	Maintenance	
	Labor and materials[6]	2%(ESP), 4%(FF), 8%(VS) of installed cost
	Replacement parts[6]	5% installed cost (FF) 3% installed cost (VS and ESP)
V.	Fixed costs	
	Annualized capital charges[6]	13.2% Installed cost (FF and ESP)[c] 16.3% Installed cost (Scrubber)[c]
	Taxes, insurance, administration, plant overhead, miscellaneous[7]	4% Installed cost
VI.	Solid waste disposal	0
VII.	Wastewater treatment	0
VIII.	Product recovery credit[d]	$20/ton[8]

[a] Most processes operate 80% of the time (7000 h/yr); however, some may operate less.

[b] Labor requirements vary with size and type of equipment.

[c] Equipment life (ESP and FF) is assumed to be 15 years and compounded interest, 10%. Equipment life of scrubber is assumed to be 10 years.

[d] Grinding operation only.

Table 4-7. CHARACTERISTICS OF PHOSPHATE ROCK DRYER EXHAUST GASES AND EMISSIONS

(SI units)

Production rate, Mg/h	45	181	272
Throughput rate, Mg/h[a]	50	200	302
Exhaust flow rate, m^3/s[b]	11	44	66
Temperature, °K	394	394	394
Moisture content, %vol.	25	25	25
Dust loading, g/dry std. m^3	12	12	12
Emission rate, kg/h[c]	256	1024	1534
Outlet emissions, kg/h			
SIP_1[d,e]	21.4	26.8	29.1
SIP_2[f,g]	15.0	18.6	20.0
AEL[h]	2.1	8.2	12.2
Required efficiency, %[i]			
SIP_1	91.7	97.4	98.1
SIP_2	94.1	98.2	98.7
AEL	99.4	99.4	99.4

[a] Assumed a 10 percent weight loss during drying.

[b] Based on an average 0.18 std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ product.

[c] Calculated from 12 g/dry std. m^3, generally a high dust loading.

[d] Regulation for all states except Florida (see Appendix B).

[e] Mass emissions at SIP_1 levels correspond to 1.0, 0.31, and 0.23 g/dry std. m^3 for the small, medium, and large model dryers, respectively.

[f] Florida regulation for existing sources (see Appendix B).

[g] Mass emissions at SIP_2 levels correspond to 0.71, 0.22, and 0.16 g/dry std. m^3 for the small, medium, and large model dryers, respectively.

[h] Based on AEL of 0.07 g/dry std. m^3 for dryers.

[i] Calculated from the above data and may vary significantly from one dryer operation to another.

Table 4-7a. CHARACTERISTICS OF PHOSPHATE ROCK DRYER EXHAUST GAS AND EMISSIONS
(English units)

Production rate, tons/h	50	200	300
Throughput rate, tons/h[a]	56	222	333
Exhaust flow rate, acfm[b]	23,400	93,500	140,000
Temperature, °F	250	250	250
Moisture content, % vol.	25	25	25
Dust loading, gr/dscf	5	5	5
Emission rate, lb/h[c]	563	2,252	3,375
Outlet emissions, lb/hr			
SIP_1[d,e]	47	59	64
SIP_2[f,g]	33	41	44
AEL[h]	4.5	18	26.9
Required efficiency, %[i]			
SIP_1	91.7	97.4	98.1
SIP_2	94.1	98.2	98.7
AEL	99.4	99.4	99.4

[a] Assumed a 10 percent weight loss during drying.

[b] Based on an average 350 scfm per ton/hr product.

[c] Calculated from 5 gr/dscf generally a high dust loading.

[d] Regulation for all states except Florida (see Appendix B).

[e] Mass emissions at SIP_1 levels correspond to 0.42, 0.13, and 0.10 gr/dscf for the small, medium, and large model dryers, respectively.

[f] Florida regulations for existing sources (see Appendix B).

[g] Mass emissions at SIP_2 levels correspond to 0.30, 0.090, and 0.065 gr/dscf for the small, medium, and large model dryers, respectively.

[h] Based on AEL of 0.031 gr/dscf for dryers.

[i] Calculated from the above data and may vary significantly from one operation to another.

The exhaust gas characteristics and required control efficiency are shown in Table 4-7 for the three emission levels: AEL, SIP_1, and SIP_2. Alternative control techniques for which costs are developed are the venturi scrubber, fabric filter, and electrostatic precipitator.

A. Fabric Filter

Pulse-jet fabric filters, which operate at a system pressure drop of about 1 kPa (4 in. WG) and filtering velocity of 3 cm/s (6 ft/min), were selected. Polypropylene bags are recommended. A temperature control system should be included in the design to prevent overheating or condensation, a serious problem encountered on this application. The temperature control system consists of temperature detectors, a transmitter, a position adjusting controller, a chart recorder, a valve-drive mechanism, and an alarm. Mineral wool insulation with aluminum casing will be provided for the ductwork and fabric filter housing to prevent excessive temperature drop and maintain the temperature at 28°C (50°F) above the dew point. The fabric filter inherently achieves very high collection efficiencies (99%+), hence no cost differentiation can be made between the three control levels. System components included in capital costs are fabric filter, fan system, stack, ductwork, expansion joints, damper, insulation, and temperature control system.

B. Venturi Scrubber

Costs were estimated for a venturi scrubbing system to achieve the three control levels for each model dryer. Accurate particle size data must be available to predict the relationship between pressure drop and collection efficiency. Moreover, efficiency and pressure drop requirements vary significantly from one dryer to another because of the variation in inlet dust loading, as well as the particle size. Tests on two dryer scrubbing systems indicated a 3kPa (12 in. WG) pressure drop would achieve a 91 percent efficiency and a 7.5 kPa (30 in. WG) pressure drop would achieve a 96.2 percent efficiency.[9]

For the purposes of estimating capital and annualized costs and to differentiate between the cost of the three control levels, it is assumed that a venturi pressure drop of 3.8 kPa (15 in. WG), 5 kPa (20 in. WG), and 7.5 kPa (30 in. WG) will generally achieve emission levels designated by SIP_1, SIP_2, and AEL, respectively.[9]

An increased design pressure drop across a scrubber will increase the capital cost of the complete system by (1) increasing the cost of the fan system (higher power requirements) and (2) increasing the costs of the ductwork and venturi (extra thickness for additional strength). The capital cost increase for an additional 1 kPa (4 in. WG) pressure drop is insignificant; however, the incremental capital costs become significant when design pressure drops are increased by 3 to 5 kPa (12 to 20 in. WG).

Increases in pressure drop directly affect annual costs mainly because of increased power costs. For example, if the pressure drop is doubled, the power costs are also doubled. This can significantly affect the annual operating costs. An increase in fixed charges (and other annual cost components, which are dependent on capital investment) will also increase annualized costs.

System components include the venturi scrubber, fan system, dampers, expansion joints, ductwork, stack, retention tank, and pump. A stainless steel venturi, ductwork, and fan may be necessary when sulfur dioxide content of the exhaust gases is high because of combustion of sulfur-bearing fuel oil in the dryer furnace.

C. Electrostatic Precipitator

Design and cost estimations of electrostatic precipitators are more difficult than for fabric filters and wet scrubbers, since the size of the unit depends on particulate drift velocity, which is not a well-quantified value.

One actual ESP installation on a phosphate rock dryer was designed for 90 percent particulate removal at 88.3 m^3/s (187,000 acfm). The total ESP plate area was 4700 m^2

($50,600\ ft^2$), corresponding to a particle drift velocity of 4.3 cm/s (8.5 ft/min).[10] This calculated drift velocity will vary from one dryer to another depending mainly on the composition of the dust, temperature, and moisture content. However, this velocity will be used for the basis of sizing the ESP's on the model dryers.

The plate area required for each flow rate and efficiency (Table 4-7) is calculated by the following equation:

$$A = -\frac{Q}{\omega}\ln(1-\eta)$$

where ω = drift velocity, 0.043 m/s (8.5 ft/min)
Q = gas flow rate, m^3/s (acfm)
η = fractional efficiency
A = plate area, m^2 (ft^2)

A direct relationship occurs between the plate area and the base purchase price of the ESP. ESP costs, which represent flange-to-flange costs, are based on vendor quotations.[11]

Equipment items included in the capital cost estimates are the ESP, hopper, screw conveyor, transformer, rectifier, fan system, ductwork, insulation, and stack.

4.2.2 Control Costs

Tables 4-8 through 4-10 summarize control costs for each control alternative and emission level for each model dryer. These costs represent those for retrofitted systems only.

Table 4-8. CAPITAL AND ANNUAL CONTROL COSTS FOR FABRIC FILTERS SERVING MODEL DRYERS

Capacity, Mg/h (tons/h)	46 (50)	181 (200)	272 (300)
Volume, m^3/s (10^3 acfm)	11 (23.4)	44 (93.5)	66 (140)
Temperature, °K (°F)	394 (250)	394 (250)	394 (250)
Equipment cost[a]	65	192	290
Direct cost	129	384	580
Indirect cost	47	139	211
Contingency cost	35	105	158
Retrofit cost	42	126	190
Total capital cost[a]	253	754	1139
Direct operating cost	46	123	173
Annual capital charges	44	130	196
Total annual cost[a]	90	253	369
Cost-effectiveness, ¢/kg(¢/lb)[b]	5.1(2.3)	3.5(1.6)	3.5(1.6)

[a] Carbon steel construction. For stainless steel construction, multiply capital costs by 1.95 and annual costs by 1.60.

[b] Calculated at AEL control, 99.2 percent efficiency.

Table 4-9. CAPITAL AND ANNUAL CONTROL COSTS FOR VENTURI SCRUBBING SYSTEMS SERVING MODEL DRYERS

($\$10^3$, 4th qtr. 1977)

Capacity, Mg/h (tons/h) Volume, m^3/s (10^3 acfm) Temperature, °K (°F)	45 (50) 11 (23.4) 394 (250)			181 (200) 44 (93.5) 394 (250)			272 (300) 66 (140) 394 (250)		
	SIP_1	SIP_2	AEL	SIP_1	SIP_2	AEL	SIP_1	SIP_2	AEL
Equipment cost[a]	60	63	68	140	161	182	204	220	251
Direct cost	130	136	148	321	370	419	484	521	595
Indirect cost	47	48	54	115	133	151	174	188	214
Contingency cost	36	37	41	89	101	115	133	143	165
Retrofit cost	43	45	49	105	122	138	159	171	196
Total capital cost[a]	256	266	291	630	726	823	950	1023	1168
Direct operating cost	65	70	83	170	200	250	249	286	361
Annual capital charges	52	54	59	128	147	167	193	208	237
Total annual costs[a]	117	124	142	298	347	417	442	494	598
Cost-effectiveness, ¢/kg (¢/lb) pollutant removed	7.0 (3.2)	7.3 (3.3)	7.9 (3.6)	4.2 (1.9)	4.8 (2.2)	5.9 (2.7)	4.2 (1.9)	4.6 (2.1)	5.7 (2.6)

[a] Carbon steel construction. For complete stainless steel construction, multiply capital costs by 2.65 and annual costs by 2.1.

Table 4-10. CAPITAL AND ANNUAL COSTS FOR ELECTROSTATIC PRECIPITATOR SYSTEMS SERVING MODEL DRYERS

($\$10^3$, 4th qtr. 1977)

Capacity, Mg/h (tons/h) Volume, m^3/s (10^3 acfm) Temperature, °K (°F)	45 (50) 11 (23.4) 394 (250)			181 (200) 44 (93.5) 394 (250)			272 (300) 66 (140) 394 (250)		
Control level	SIP_1	SIP_2	AEL	SIP_1	SIP_2	AEL	SIP_1	SIP_2	AEL
Equipment cost[a]	283	293	353	556	578	606	670	690	710
Direct cost	563	583	703	1107	1147	1207	1335	1375	1415
Indirect cost	203	210	253	399	413	345	481	495	508
Contingency cost	155	160	194	304	315	332	368	378	389
Retrofit cost	185	192	231	363	375	396	437	452	466
Total capital cost[a]	1105	1145	1380	2173	2250	2370	2621	2700	2778
Direct operating cost	99	81	97	167	175	185	217	225	233
Annual capital charges	190	197	237	374	387	408	451	464	478
Total annual costs	269	278	334	541	562	593	668	689	711
Cost-effectiveness, ¢/kg (¢/lb) pollutant removed	16.3 (7.4)	16.5 (7.5)	18.7 (8.5)	7.7 (3.5)	7.9 (3.6)	8.4 (3.8)	6.4 (2.9)	6.6 (3.0)	6.6 (3.0)

[a] Carbon steel construction. To estimate costs for stainless steel construction, multiply capital costs by 3 and annual costs by 2.8.

A. Fabric Filter

Table 4-8 summarizes capital and annualized costs for fabric filter systems. There is no differentiation between degree of control, since fabric filters will inherently maintain a very high collection efficiency. For this purpose it is assumed to maintain an efficiency of 99.2 percent, corresponding to AEL control. The costs are graphically illustrated in Figure 4-1 and are plotted as costs versus flow rate to allow cost estimating for site-specific cases. If stainless steel construction is required, capital costs are multiplied by a factor of 1.95 and annualized costs are multiplied by a factor of 1.60.

B. Venturi Scrubber

Table 4-9 summarizes capital and annualized costs for venturi scrubbing systems. Significant increases in costs occur as pressure drop (efficiency) increases. Capital costs are shown as a function of flow rate in Figure 4-1 to allow cost estimating for site-specific cases. Other capital cost estimates are compared to those generated in this report. To obtain costs for stainless steel construction, multiply capital costs by 2.65 and annualized costs by 2.1.

C. Electrostatic Precipitator

Table 4-10 summarizes the control costs for electrostatic precipitators on the model dryers. Costs increase moderately with efficiency (plate area). Capital costs are shown as a function of flow rate in Figure 4-1 to allow cost estimating for site-specific cases. The capital costs generated by this study are compared with other cost estimates in Figure 4-1. To obtain costs for stainless steel systems, multiply capital costs by 3.0 and annualized costs by 2.8.

4.2.3 Cost-effectiveness

The cost-effectiveness of the control alternatives can be expressed in terms of cost per unit weight of pollutant removed. Tables 4-8 through 4-10 indicate the cost-effectiveness for each application. Figure 4-2 shows the variation of cost-effectiveness with the size of control system and process. This plot applies only to the model processes and is not suitable to estimate costs for specific cases.

Fabric filtration is the most cost-effective alternative if maintenance costs can be kept low; however, its technical feasibility has been questioned by many operators (see Section 3.4.3). The most probable control alternative is the venturi scrubber, for which costs increase moderately with level of control. Electrostatic precipitators are far more expensive, except for the large dryer at the most stringent control level. Here, ESP's may be economically attractive, especially when high pressure drops [7 to 10 kPa (30 to 40 in. WG)] are required for scrubbers. This is

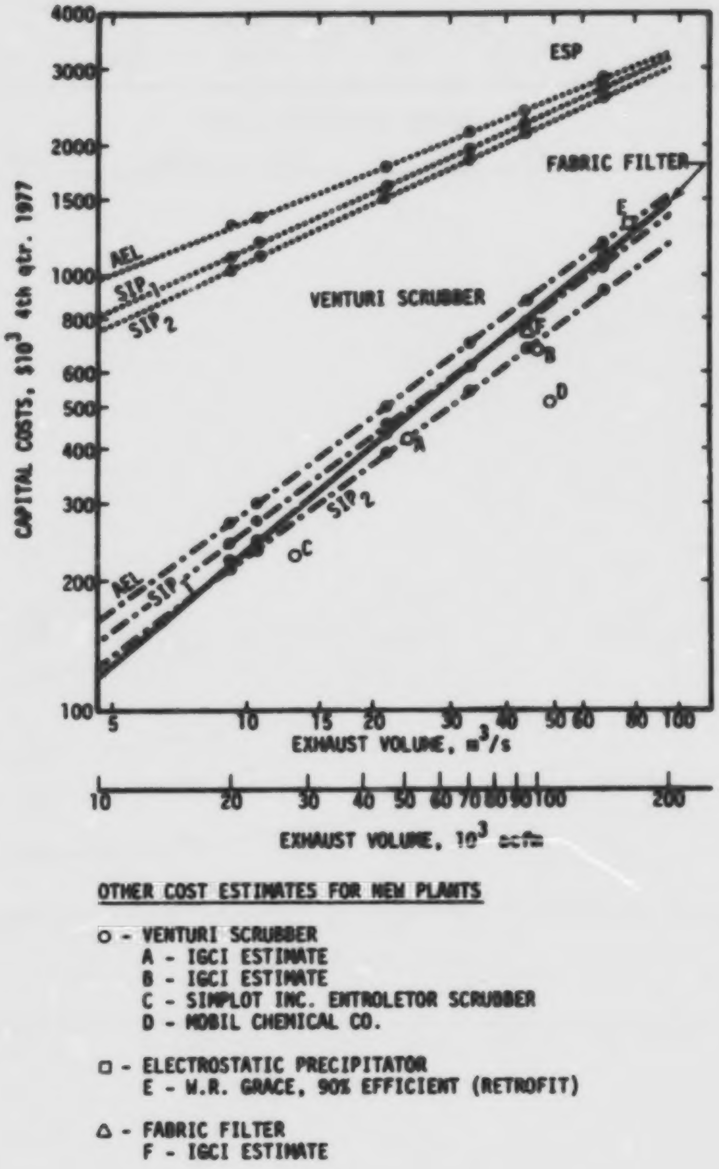

Figure 4-1. Capital costs for control alternatives for dryers and calciners.

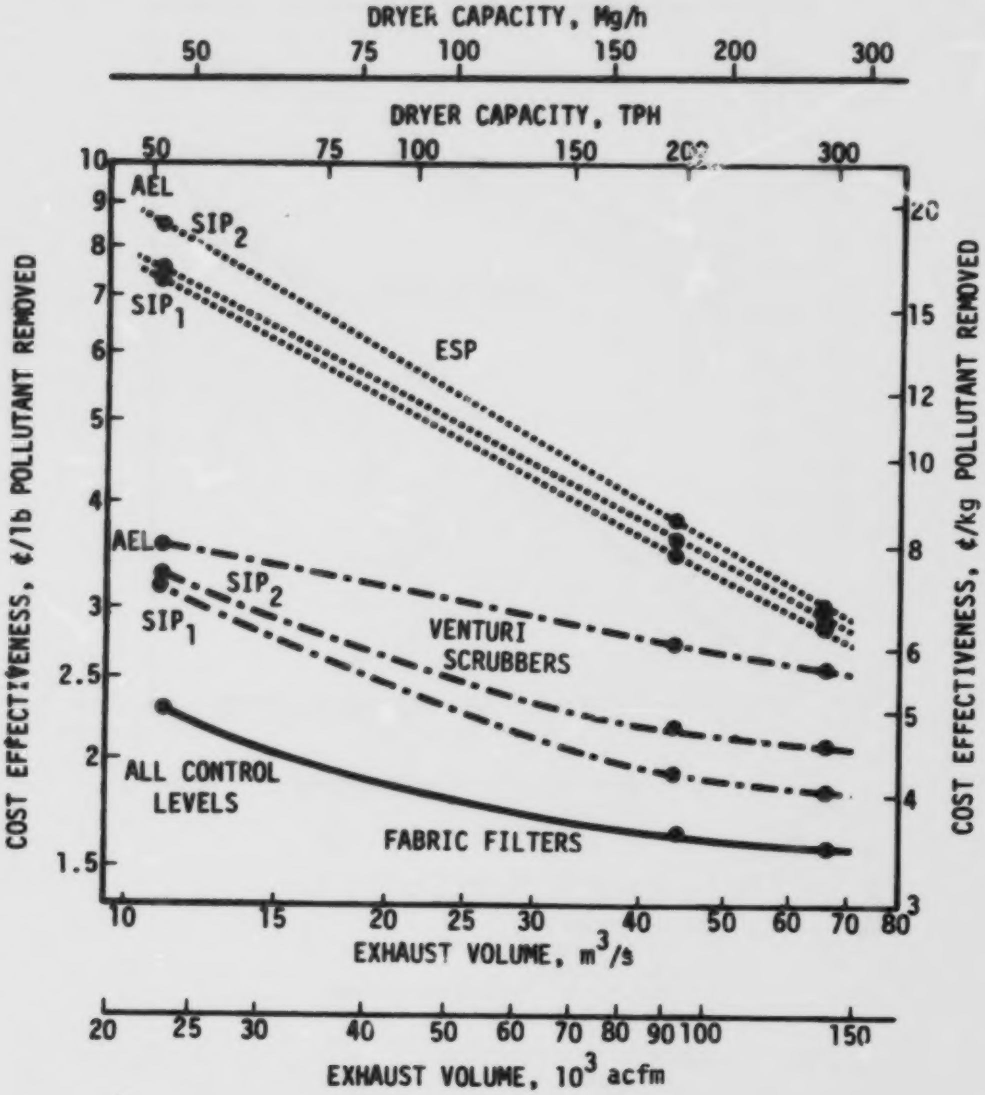

Figure 4-2. Cost effectiveness of control alternatives for model dryers.

indicated by the ESP cost-effective curve approaching the curve for scrubbers in Figure 4-2.

4.3 CALCINING

Three model calciners were selected for the control cost analyses as shown in Table 4-11. Control systems for calciners are identical to those for dryers. Hence, control costs for a specific exhaust volume will also be identical. Figure 4-1 is used to estimate control costs for calciners.

4.3.1 Model Process Parameters

Exhaust gas characteristics and required control efficiency are shown in Table 4-11 for the three control levels. Alternative control techniques for which costs are developed are the venturi scrubber, fabric filter, and electrostatic precipitator. Emissions from calciners are similar to those of dryers. Control costs are identical to those for dryers based on exhaust volume. Therefore no additional discussion of control system design parameters is necessary.

4.3.2 Control Costs

A. Fabric Filter

Table 4-12 shows annualized and capital costs for the fabric filter systems serving the model calciners. For stainless steel construction, capital costs are multiplied by a factor of 1.95 and annualized costs are multiplied by

Table 4-11. CHARACTERISTICS OF MODEL CALCINER EXHAUST GASES AND EMISSIONS

(SI units)

Production rate, Mg/h	18	41	64
Throughput rate, Mg/h[a]	20	45	71
Exhaust flow rate, m^3/s[b]	9.5	21.4	33.2
Temperature, °K	394	394	394
Moisture content, %vol.	25	25	25
Dust loading, g/dry std. m^3	12	12	12
Emission rate, kg/h[c]	219	493	767
Outlet emissions, kg/hr			
SIP_1[d,e]	14.5	19.1	21.8
SIP_2[f,g]	10.9	14.1	15.9
AEL[h]	1.4	3.2	4.5
Required efficiency, %[i]			
SIP_1	93.4	96.1	97.2
SIP_2	95.0	97.1	97.9
AEL	99.4	99.4	99.4

[a] Assumed 10 percent weight loss during calcining.

[b] Calculated at 0.39 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ product; gases are cooled to 394°K by a process heat exchanger.

[c] Calculated from 12 g/dry std. m^3 and 25% vol. moisture.

[d] Regulation for all states except Florida (see Appendix B).

[e] Mass emissions for SIP_1 levels correspond to 0.79, 0.47, and 0.34 g/dry std. m^3 for small, medium, and large calciners, respectively.

[f] Florida regulations for existing sources (see Appendix B).

[g] Mass emissions for SIP_2 levels correspond to 0.60, 0.35, and 0.25 g/dry std. m^3 for small, medium, and large calciners, respectively.

[h] Based on AEL of 0.07 g/dry std. m^3 for calciners.

[i] Calculated from the above data and may vary significantly from one operation to another.

Table 4-11a. CHARACTERISTICS OF MODEL CALCINER EXHAUST GASES AND EMISSIONS

(English units)

Production rate, tons/h	20	45	70
Throughput rate, tons/h[a]	22	50	78
Exhaust flow rate, acfm[b]	20,100	45,200	70,300
Temperature, °F	250	250	250
Moisture content, % vol.	25	25	25
Dust loading, gr/dscf	5	5	5
Emission rate, lb/h[c]	482	1085	1688
Outlet emissions, lb/h			
SIP_1[d,e]	32	42	48
SIP_2[f,g]	24	31	35
AEL[h]	3	7	10
Required efficiency, %[i]			
SIP_1	93.4	96.1	97.2
SIP_2	95.0	97.1	97.9
AEL	99.4	99.4	99.4

[a] Assumed 10 percent weight loss during calcining.

[b] Calculated at 750 scfm per tons/h product; exhaust gases are cooled to 250°F by aftercooler.

[c] Calculated from 5 gr/dscf and 25% vol. moisture.

[d] Regulation for all states except Florida (see Appendix B).

[e] Mass emissions for SIP_1 levels correspond to 0.33, 0.20, and 0.14 gr/dscf for small, medium, and large calciners, respectively.

[f] Florida regulations for existing sources (see Appendix B).

[g] Mass emissions for SIP_2 levels correspond to 0.25, 0.15, and 0.10 gr/dscf for small, medium, and large calciners, respectively.

[h] Based on AEL of 0.031 gr/dscf for calciners.

[i] Calculated from the above data and may vary significantly from one operation to another.

Table 4-12. CAPITAL AND ANNUAL COSTS FOR FABRIC FILTER SYSTEMS SERVING MODEL CALCINERS

($\$10^3$, 4th qtr. 1977)

Capacity, Mg/h (tons/h)	18 (20)	41 (45)	63 (70)
Exhaust volume, m^3/s (10^3 acfm)	9.5 (20.1)	21.3 (45.2)	33.2 (70.3)
Temperature, °K (°F)	394 (250)	394 (250)	394 (250)
Equipment cost[a]	57	113	160
Direct cost	113	225	320
Indirect cost	41	81	117
Contingency cost	31	61	88
Retrofit cost	37	73	105
Total capital cost[a]	222	440	630
Direct operating cost	42	69	102
Annual capital charges	38	76	108
Total annual cost	80	145	210
Cost-effectiveness, ¢/kg (¢/lb) pollutant removed	5.3 (2.4)	4.2 (1.9)	4.0 (1.8)

[a] Carbon steel construction. For stainless steel construction multiply capital costs by 1.95 and annual costs by 1.60.

1.6. Figure 4-1 graphically illustrates the variation of calciner control costs with the exhaust volumetric rate.

B. Venturi Scrubbers

Table 4-13 shows the capital and annualized costs for the venturi scrubbing systems serving the model calciners. Note the moderate increase in costs as the pressure drop (efficiency) increases. To estimate costs for complete stainless steel construction, multiply the capital costs by 2.65 and the annualized costs by 2.1. In Figure 4-1 capital costs are plotted as a function of exhaust flow rate.

C. Electrostatic Precipitators

Table 4-14 shows the capital and annualized costs for the ESP systems serving the model calciners. Note the increase in capital costs as the efficiency (ESP plate area) increases. ESP systems are far more expensive than fabric filters or venturi scrubbers. To estimate control costs for stainless steel construction, multiply the capital costs by a factor of 3.0 and the annualized costs by 2.8. Figure 4-1 illustrates the ESP capital costs as a function of exhaust flow rate.

4.3.3 Cost-effectiveness

The cost-effectiveness curves for each control alternative are shown in Figure 4-3. Fabric filtration is the most cost-effective control method. ESP's are far less cost

Table 4-13. CAPITAL AND ANNUAL COSTS FOR VENTURI SCRUBBING SYSTEMS SERVING MODEL CALCINERS
($$10^3$, 4th qtr. 1977)

Capacity, Mg/h (tons/h) Volume, m^3/s (10^3 acfm) Temperature, °K (°F)	18 (20) 9.5 (20.1) 394 (250)			41 (45) 21.3(45.2) 394 (250)			63 (70) 33.2 (70.3) 394 (250)		
Control level	SIP_1	SIP_2	AEL	SIP_1	SIP_2	AEL	SIP_1	SIP_2	AEL
Equipment cost[a]	98	111	121	173	200	268	240	271	307
Direct cost	107	122	134	194	224	301	276	311	352
Indirect cost	39	44	48	70	81	108	100	112	127
Contingency cost	29	33	36	53	61	82	75	85	96
Retrofit cost	35	41	43	63	74	99	89	102	115
Total capital cost[a]	210	240	263	380	440	590	540	610	690
Direct operating cost	57	66	77	103	111	113	140	156	190
Annual capital charges	43	499	53	77	89	120	110	124	140
Total annual costs	100	115	130	180	200	233	250	280	330
Cost-effectiveness, ¢/kg (¢/lb) pollutant removed	7.0 (3.2)	7.9 (3.6)	8.6 (3.9)	5.5 (2.5)	5.9 (2.7)	6.8 (3.1)	4.8 (2.2)	5.3 (2.4)	6.2 (2.8)

[a] Carbon steel construction. To estimate costs for stainless steel construction, multiply capital costs by 2.65 and annual costs by 2.1.

Table 4-14. CAPITAL AND ANNUAL COSTS FOR ELECTROSTATIC PRECIPITATORS SERVING MODEL CALCINERS

($\$10^3$, 4th qtr. 1977)

Capacity, Mg/h (tons/h) Volume, m^3/s (10^3 acfm) Temperature, °K (°F)	18 (20) 9.5 (20.1) 394 (250)			41 (45) 21.3 (45.2) 394 (250)			63 (70) 33.2 (70.3) 394 (250)		
Level of control	SIP_1	SIP_2	AEL	SIP_1	SIP_2	AEL	SIP_1	SIP_2	AEL
Equipment cost[a]	268	280	338	382	408	458	424	509	548
Direct cost	535	560	662	764	816	917	968	1019	1095
Indirect cost	195	203	240	277	296	333	351	270	397
Contingency	145	152	180	208	222	249	263	277	298
Retrofit cost	175	185	218	251	268	301	218	334	360
Total capital cost	1050	1100	1300	1500	1600	1800	1900	2000	2150
Direct operating cost	79	81	96	117	120	130	138	141	160
Annual capital charges	181	189	224	258	275	310	327	344	370
Total annual cost	260	270	320	375	395	440	465	485	530
Cost-effectiveness, ¢/kg	18.3	18.5	20.9	11.2	11.7	12.8	9.0	9.0	9.9
(¢/lb) pollutant removed	(8.3)	(8.4)	(9.5)	(5.1)	(5.3)	(5.8)	(4.1)	(4.1)	(4.5)

[a] Carbon steel construction. To estimate costs for stainless steel construction, multiply capital costs by 3 and annual costs by 2.8.

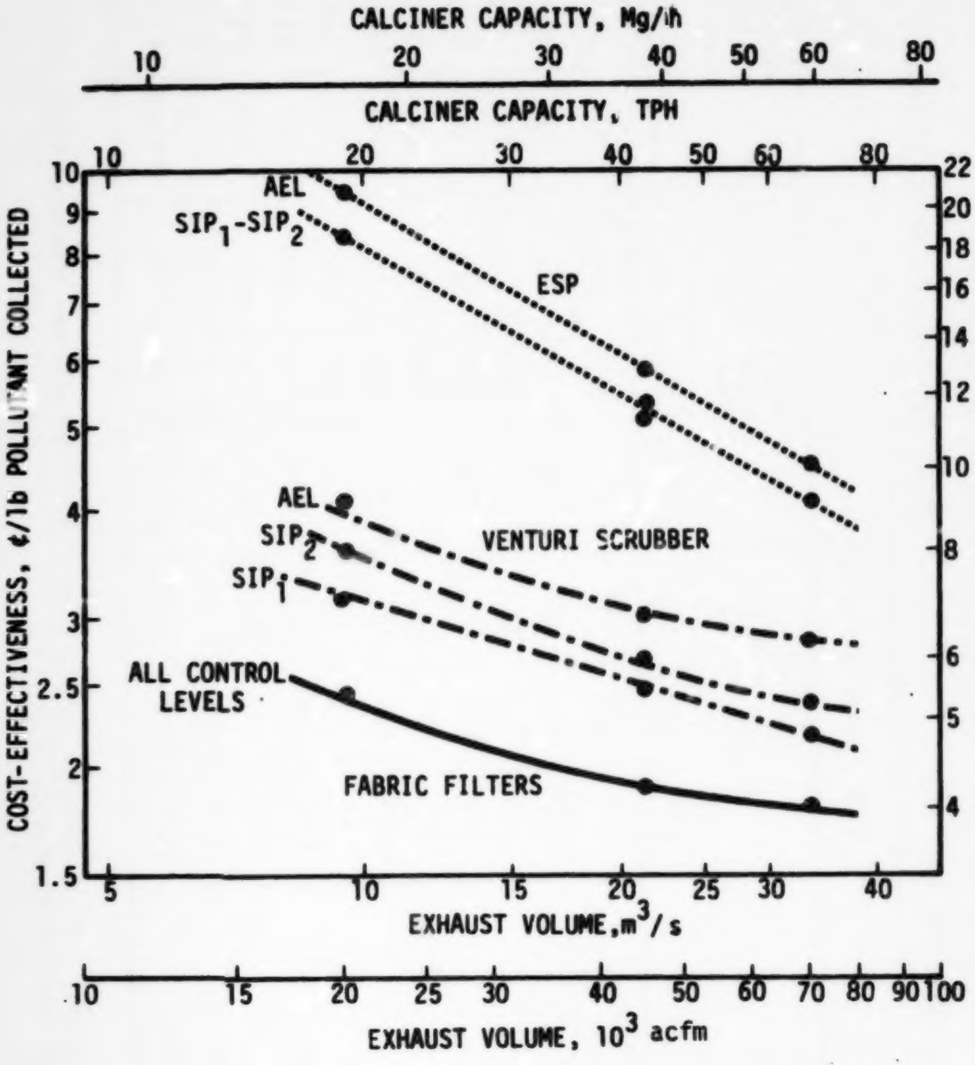

Figure 4-3. Cost-effectiveness curves for calciner emission control alternatives.

effective as scrubbing and fabric filtration except for very large calciners. This is indicated by the ESP curve approaching the scrubber curve for large capacities. ESP cost-effectiveness for SIP_1 and SIP_2 control levels is essentially the same. These curves are for the model calciners only and are not suitable for cost estimating for specific cases.

4.4 GRINDING

4.4.1 Model Process Parameters

Three model grinders were chosen for the control cost analysis as shown in Table 4-15. Exhaust gas characteristics and required emission levels are shown in Table 4-15. The alternative control techniques for which costs are developed are the fabric filter and venturi scrubber.

A. Fabric Filter

Pulse-jet fabric filters, which operate at a filtering velocity of 3 cm/s (6 ft/min) and a pressure drop of 1 kPa (4 in. WG), were selected to control emissions. Polyester or polypropylene bags are suitable for this application. The temperature rarely exceeds 310°K (100°F); however, exhaust moisture content can be a potential problem in some situations. No temperature control system or insulation is required. The fabric filter inherently achieves very high collection efficiencies (99+ percent); hence, no cost differentiation can be made between the three levels of control.

Table 4-15. CHARACTERISTICS OF EXHAUST GAS AND EMISSIONS FROM MODEL PHOSPHATE ROCK GRINDERS

(SI units)

Production rate, Mg/h	45	91	136
Throughput rate, Mg/h	45	91	136
Exhaust flow rate, actual m^3/s[a]	2.6	5.2	7.8
Temperature, °K	322	322	322
Moisture content, % vol.	5	5	5
Dust loading, g/dry std. m^3	12	12	12
Emission rate, kg/h[b]	92.7	185	278
Outlet emissions, kg/h[b]			
SIP_1[c,d]	20	22.7	25
SIP_2[e,f]	14.5	16.4	17.3
AEL[g]	0.26	0.56	0.8
Required efficiency, %[h]			
SIP_1	78.4	87.7	91.2
SIP_2	84.3	91.2	93.8
AEL	99.7	99.7	99.7

[a] Based on an average 0.052 dry std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ product.

[b] Calculated from dust loading and exhaust flow rate.

[c] Based on least stringent regulation (see Appendix B).

[d] Mass emissions for SIP_1 levels correspond to 2.60, 1.48, and 1.06 g/dry std. m^3 for small, medium, and large grinders, respectively.

[e] Based on most stringent regulation (see Appendix B).

[f] Mass emissions for SIP_2 levels correspond to 1.88, 1.06, and 0.74 g/dry std. m^3 for small, medium, and large grinders, respectively.

[g] Based on AEL of 0.03 g/dry std. m^3 for grinders.

[h] Efficiency required may vary significantly from one operation to another.

Table 4-15a. CHARACTERISTICS OF EXHAUST GAS AND EMISSIONS FROM MODEL PHOSPHATE ROCK GRINDERS

(English units)

Production rate, tons/h	50	100	150
Throughput rate, tons/h	50	100	150
Exhaust flow rate, acfm[a]	5,500	11,000	16,500
Temperature, °K	120	120	120
Moisture content, % vol.	5	5	5
Dust loading, gr/dscf	5	5	5
Emission rate, lb/h[b]	204	408	612
Outlet emissions, lb/h			
SIP_1[c,d]	44	50	54
SIP_2[e,f]	32	36	38
AEL[g]	0.58	1.16	1.75
Required efficiency, %[h]			
SIP_1	78.4	87.7	91.2
SIP_2	84.3	91.2	93.8
AEL	99.7	99.7	99.7

[a] Based on an average 100 scfm per ton/hr product.

[b] Calculated from dust loading and exhaust flow rate.

[c] Based on least stringent regulation (see Appendix B).

[d] Mass emissions for SIP_1 levels correspond to 1.08, 0.62, and 0.44 gr/dscf for small, medium, and large grinders, respectively.

[e] Based on most stringent regulation (see Appendix B).

[f] Mass emissions for SIP_2 levels correspond to 0.78, 0.44, and 0.31 gr/dscf for small, medium, and large grinders, respectively.

[g] Based on AEL of 0.013 gr/dscf for grinders.

[h] Efficiency required may vary significantly from one operation to another.

System components in the equipment cost include the fabric filter, ductwork, fan system, damper, and stack.

B. Venturi Scrubber

Venturi scrubbing systems for grinding facilties are essentially the same for dryers and grindings, however, no insulation or temperature control system is required. No credits for the dust collected can be accounted since the dust is in a slurry form. Components included in the equipment costs are the venturi scrubber, tank, pump, fan system, ductwork, venturi throat, and stack.

4.4.2 Control Costs

In estimating the control costs for the fabric filter and venturi scrubbing systems, no costs were assumed to be associated with wastewater treatment or solid waste disposal. An annual operating time of 7000 hours is assumed.

A. Fabric Filter

Table 4-16 shows the capital and annualized costs for the fabric filter systems serving the model grinders. A product recovery credit of \$22/Mg (\$20/ton) of dust collected is applied, constituting a very significant savings. To obtain control costs for stainless steel systems, multiply the capital costs by 2.3 and the annualized costs by 1.8. Figure 4-4 illustrates capital costs as a function of exhaust volume.

Table 4-16. CAPITAL AND ANNUAL COSTS FOR FABRIC FILTER SYSTEMS SERVING MODEL GRINDERS
($\$10^3$, 4th qtr. 1977)

Capacity, Mg/h (tons/h)	45 (50)	91 (100)	136 (150)
Exhaust volume, m^3/s (10^3 acfm)	2.6 (5.5)	5.2 (11.0)	7.8 (16.5)
Temperature, °K (°F)	322 (120)	322 (120)	322 (120)
Equipment cost[a]	16	32	51
Direct cost	33	70	112
Indirect cost	12	25	41
Contingency cost	9	19	31
Retrofit cost	11	22	36
Total capital cost[a]	65	136	220
Direct operating cost	23	31	39
Annual capital charges	11	23	38
Product recovery credit	14	29	43
Total annual cost	20	25	34
Cost-effectiveness, ¢/kg (¢/lb) pollutant removed	3.1 (1.4)	1.9 (0.88)	1.8 (0.80)

[a] To estimate costs for stainless steel construction, multiply capital costs by 2.3 and annual costs by 1.8.

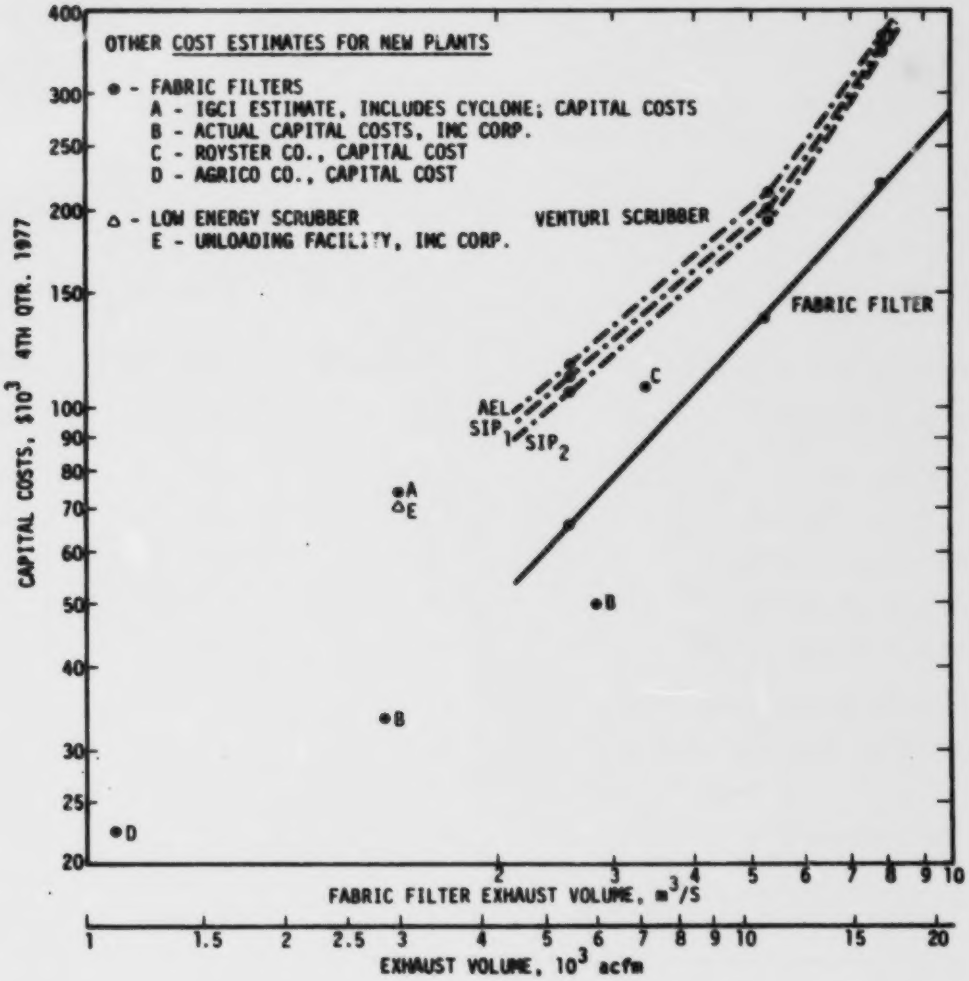

Figure 4-4. Capital costs for fabric filter and venturi scrubbing systems serving model grinders.

B. Venturi Scrubber

Table 4-17 shows the capital and annualized costs for the venturi scrubbing systems serving the model grinders. Note the slight increase of costs with efficiency (pressure drop). Annualized costs increase with efficiency mainly because of power requirements. No product recovery credit is applied against annual costs since the wet slurry is not in a recoverable state. To obtain control costs for complete stainless steel systems, multiply the capital costs by 2.65 and the annualized costs by 2.1. Figure 4-4 illustrates control cost as a function of exhaust volume.

4.4.2 Cost-effectiveness

Figure 4-5 illustrates the cost-effectiveness for the grinder control options. Fabric filters are, by far, the most cost-effective control method, primarily because of lower energy requirements and the product recovery credits. Cost-effectiveness for venturi scrubbing increases from medium to large grinders because of the large increase in capital charges and power requirements, which offset the increase in pollutant collection.

4.5 WET GRINDING

One viable emission control alternative for phosphate rock plants that produce phosphate for the manufacture of phosphoric acid is the installation of wet grinding equipment. The use of wet grinding eliminates the need for

Table 4-17. CONTROL COSTS FOR VENTURI SCRUBBER SYSTEMS SERVING MODEL GRINDERS

($\$10^3$, 4th qtr. 1977)

Capacity, Mg/h (tons/h)	45 (50)			91 (100)			136 (150)		
Exhaust volume, m^3/s (10^3acfm)	2.6 (5.5)			5.2 (11.0)			7.8 (16.5)		
Temperature, °K (°F)	322 (120)			322(120)			322 (120)		
Control level	SIP_1	SIP_2	AEL	SIP_1	SIP_2	AEL	SIP_1	SIP_2	AEL
Equipment cost[a]	25	26	27	45	46	49	80	81	83
Direct cost	55	57	59	98	102	107	177	179	183
Indirect cost	20	21	21	35	37	40	64	66	68
Contingency cost	15	15	16	27	28	15	48	48	49
Retrofit cost	17	18	19	32	33	18	58	58	60
Total capital costs[a]	107	111	115	192	200	210	347	352	360
Direct operating cost	32	34	37	47	50	55	76	80	88
Annual capital charges	22	23	23	39	41	43	70	71	73
Total annual costs[a]	54	57	60	86	91	98	146	151	161
Cost-effectiveness, ¢/kg (¢/lb) pollutant removed	10.8 (4.9)	10.3 (4.7)	9.2 (4.2)	7.5 (3.4)	7.7 (3.5)	7 7 (3.5)	8.4 (3.8)	8.4 (3.8)	8.4 (3.8)

[a] To estimate costs for stainless steel construction, multiply capital costs by 2.65 and annual costs by 2.1.

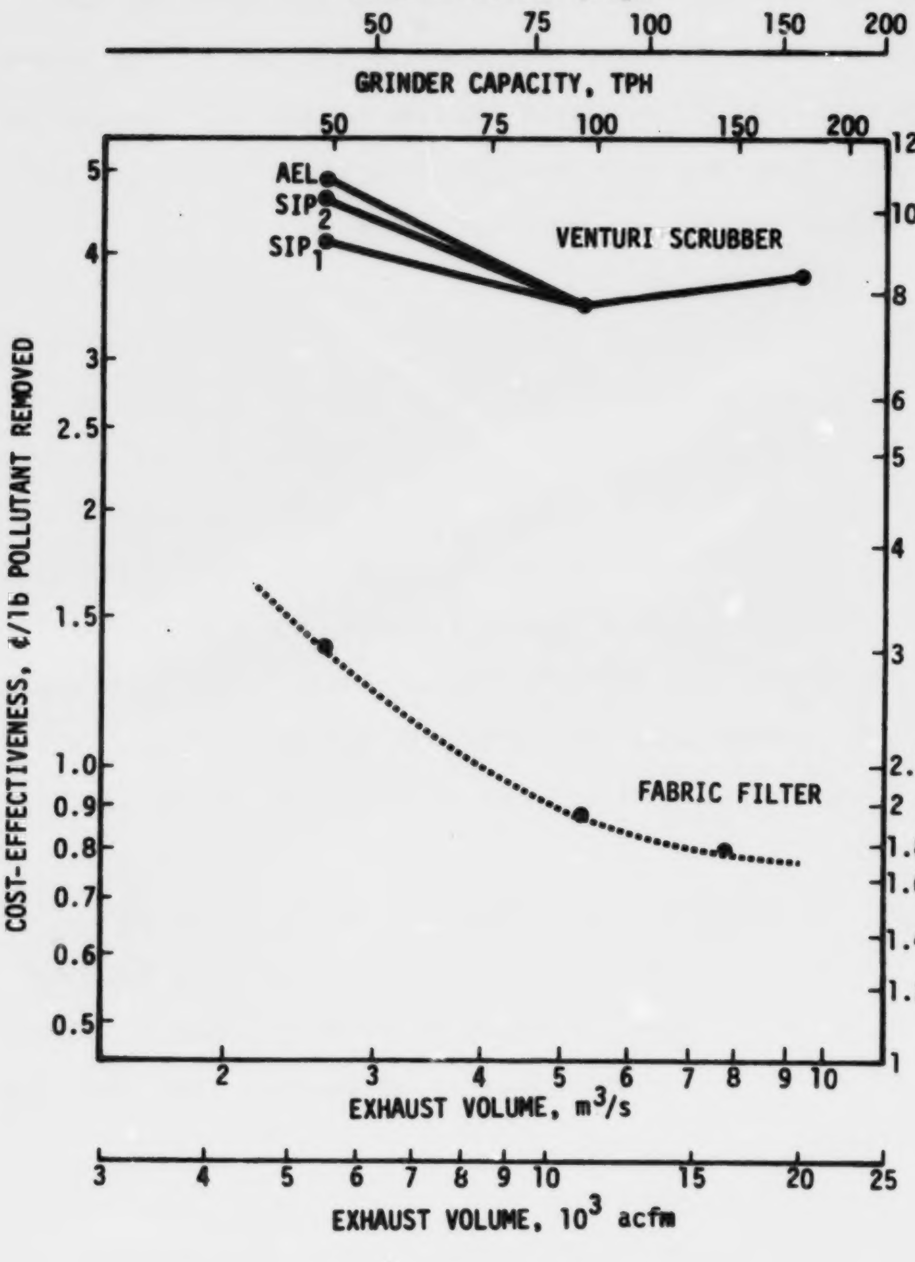

Figure 4-5. Cost-effectiveness curves for fabric filters and venturi scrubbers serving model grinders.

drying and its dust control system and the grinding dust control system. The cost savings for the use of wet grinding is difficult to estimate because of the many variables involved. However, this section attempts to quantify the cost savings associated with wet grinding.

4.5.1 Capital Costs[12]

Table 4-18 indicates and compares the capital costs for complete grinding systems for model capacities of 45 Mg/h (50 tons/h), 91 Mg/h (100 tons/h) and 136 Mg/h (150 tons/h). Grinding options include wet or dry systems and open or closed circuits. These costs vary with the type of rock and raw material and product specifications. The basis for these costs are 0.64 cm (1/4 in.) diameter inlet rock and 60 percent by weight less than 200 mesh outlet product. Moisture content within the grinder is a typical 28 to 32 percent.

For the large 136 Mg/h (150 tons/h) grinding facilities, the capital costs do not vary substantially between grinding options. For the small 45 Mg/h (50 tons/h) grinding system, the wet system cost is 35 percent less than the dry system.

4.5.2 Annualized Costs

The total operating cost for a drying operation at one plant is $1.85/ton product, including dust control and

Table 4-18. PURCHASE COSTS OF WET AND DRY GRINDING SYSTEMS

(1977 prices)[12]

Type of circuit[a]	45 Mg/h (50 tons/h)	Capacity 91 Mg/h (100 tons/h)	136 Mg/h (150 tons/h)
Dry-closed	$735,000	$990,000	$1,150,000
Dry-open[b]			
Wet-open	475,000	735,000	950,000
Wet-closed	c	c	900,000

Specifications: 1/4 in. rock inlet: 60% with ≤ 200 mesh
outlet 68-72% solids.

[a] Includes feeders, mill, classifier, motor, balls, and fans. Dry system prices include ductwork, cyclone, and fabric filter.

[b] Uncommon.

[c] Uncommon, operating problems.

capital charges. Another plant reports about $0.86/ton, including dust control.[14] These are PEDCo estimates based on information given by the companies. An average operating cost may be taken as $1.40/ton of product, thus representing part of the savings by eliminating drying and using wet grinding. Actual costs will vary depending on the type of fuel and emission control device.

The operating cost for air pollution control on grinding facilities were estimated previously in Section 4.4. The estimated annual savings by installing wet grinding is $1.65/Mg ($1.50/ton) of ground product. Table 4-19 presents an estimate of annual operating costs.

Table 4-19. ANNUAL SAVINGS AND OPERATING COSTS FOR WET GRINDING SYSTEMS

Production capacity, Mg/h (tons/h)	45 (50)	91 (100)	136 (150)
Operating time, h/yr	7000	7000	7000
Annual savings from dryer[a]	$490,000	$980,000	$1,470,000
Annual savings from grinder			
APC system[b]			
° Fabric filter	20,000	25,000	34,000
° Wet collector	60,000	98,000	161,000
Total estimated savings			
° With wet collector	550,000	1,078,000	1,630,000
° With fabric filter	510,000	1,005,000	1,500,000
Assumed annual savings[c]	530,000	1,050,000	1,600,000
Cost of new wet grinding	523,000	810,000	990,000 1,050,000
Pay-out period[c]	12 months	10 months	8 months

[a] Includes dryer operating expenses, APC control costs, and depreciation. Average savings of $1.50/Mg ($1.40/ton).

[b] Includes air pollution control system operating costs, depreciation, and product recovery (see Tables 4-16 and 4-17)

[c] Assuming wet grinding and dry grinding operating costs are the same. Includes a and b above.

[d] Assuming an installation factor of 1.10.

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5.0 ENVIRONMENTAL IMPACT OF APPLYING CONTROL TECHNOLOGY

5.1 INTRODUCTION

This section identifies the incremental environmental and energy impacts in relation to each control alternative and level of control. Analyses are based on model situations in which impacts are the highest expected. The results of the study show that significant improvement in ambient air quality is achieved by the application of controls to meet two typical State Implementation Plan emission levels (SIP_1 and SIP_2). Further improvement can be achieved by applying control technology that meets more stringent alternative emission levels (AEL). Emission levels are discussed in Appendix B in more detail. The study also indicates that maximum expected impacts on water pollution, solid waste disposal, and radiation exposure are negligible. Although energy demand increases significantly with application of control technology, the incremental increase in demand resulting from achieving AEL or SIP_2 emission levels over SIP_1 levels is negligible.

5.2 AMBIENT AIR IMPACT

An atmospheric dispersion model was used to predict the level of the ambient particulate concentrations ($\mu g/m^3$) caused by emissions from phosphate rock processes. Dispersion modeling was performed on drying, calcining, and grinding operations. Process parameters were selected within a reasonable range so as to maximize air impact and simulate "worst-case" conditions. Pollutant concentrations, estimated by state-of-the-art modeling techniques and accurate to within a factor of 2, represent 24-hour averages and annual means. Florida meteorological data were used to simulate atmospheric conditions and behavior. All pollutants are assumed to display the dispersion behavior of nonreactive gases.[1] Refer to Appendix D for a more detailed description of the modeling technique. Input and output data for the modeling program for the drying, calcining, and grinding operations are shown in Tables 5-1, 5-2, and 5-3, respectively. The results indicate it is not likely that the primary national ambient air quality standard (NAAQS) for particulate matter [260 $\mu g/m^3$ (24-h average) and 75 $\mu g/m^3$ (annual mean)] will be exceeded at the stringent control level (SIP_2).

The incremental improvement of air quality by applying SIP_1 control on a previously uncontrolled process is highly

Table 5-1. RESULTS OF DISPERSION MODELING TO DETERMINE AMBIENT IMPACT OF DRYER EMISSIONS (S.I. UNITS)

Production rate, Mg/h	45	272
Exhaust rate, m^3/s^a	14.2	85
Uncontrolled emission, g/s^b	91	845
Stack height, m	15	20
Stack diameter, m	1.34	3.3
Temperature, °K	394	394
Velocity, m/s	10	10
Building height, m	10	15

	Level of control					
	$SIP_1{}^c$	$SIP_2{}^d$	AEL^e	$SIP_1{}^c$	$SIP_2{}^d$	AEL^e
Emission, g/s	5.95	4.18	0.57	8.07	5.55	3.38
MGLC,[f] $\mu g/m^3$ @ 0.1 km	140 (19)	98 (13)	13 (1.8)	61 (5.4)	42 (3.7)	26 (2.3)
MGLC, $\mu g/m^3$ @ 0.3 km	68 (11)	48 (7.7)	6.5 (1.1)	21 (1.7)	14 (1.2)	8.9 (0.7)
MGLC, $\mu g/m^3$ @ 2 km	19 (4)	14 (2.8)	1.9 (0.4)	8.1 (1.2)	5.6 (0.8)	3.4 (0.5)
MGLC, $\mu g/m^3$ @ 20 km	1.1 (0.2)	0.78 (0.14)	0.1 (0.02)	0.8 (0.2)	0.6 (0.1)	0.3 (0.07)

[a] Based on 0.23 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ product.

[b] Based on 11.4 g/dry std. m^3 and 25% v moisture content.

[c] Based on least stringent state regulations.

[d] Based on most stringent state regulations.

[e] Based on AEL of 0.071 g/dry std. m^3.

[f] MGLC - maximum ground level concentration of particulate matter; 24-h average (annual mean)

Table 5-2. RESULTS OF DISPERSION MODELING TO DETERMINE AMBIENT IMPACT OF CALCINER EMISSION (S.I. UNITS)

Production rate, Mg/h	18.1	63.5
Exhaust rate, m^3/s[a]	12.7 (17.2)[b]	44.2 (60.2)[b]
Uncontrolled emission, g/s[c]	81.0	2284
Stack height, m	15	15
Stack diameter, m	1.27	2.38
Temperature, °K	394 (533)[b]	394
Velocity, m/s	10 (13.6)[b]	10 (13.6)[b]
Building height, m	10	10

	Level of control					
	SIP_1[d]	SIP_2[e]	AEL[f]	SIP_1[d]	SIP_2[e]	AEL[f]
Emissions, g/s	3.78	2.90	0.50	5.93	4.29	1.76
MGLC,[g] $\mu g/m^3$ @ 0.1 km	96 (13)	73 (10)	13 (1.7)	71 (6.1)	51 (4.4)	21 (1.8)
MGLC, $\mu g/m^3$ @ 0.3 km	49 (8.3)	38 (6.4)	6.6 (1.1)	23 (2)	17 (1.4)	7 (0.6)
MGLC, $\mu g/m^3$ @ 2 km	13 (2.7)	10 (2.1)	1.7 (0.4)	11 (1.8)	8 (1.3)	3.3 (0.5)
MGLC, $\mu g/m^3$ @ 20 km	0.7 (0.1)	0.5 (0.08)	0.09 (0.01)	0.7 (0.2)	0.50 (0.14)	0.2 (0.06)

[a] Based on 0.51 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ product.

[b] Exhaust rates, velocity, and temperature indicate conditions prior to cooling the gas stream.

[c] Based on 11.4 g/dry std. m^3 and 25% v moisture content.

[d] Based on least stringent state regulations.

[e] Based on most stringent state regulations.

[f] Based on AEL of 0.070 g/dry std. m^3.

[g] MGLC - maximum ground level concentration of particulate matter; 24-h average (annual mean).

Table 5-3. RESULTS OF DISPERSION MODELING TO DETERMINE AMBIENT IMPACT OF GRINDER EMISSIONS (S.I. UNITS)

Production rate, Mg/h	45	136
Exhaust rate, m^3/s[a]	4	12
Uncontrolled emissions, g/s[b]	38	117
Stack height, m	15	15
Stack diameter, m	0.71	1
Temperature, °K	373	373
Velocity, m/s	10	10
Building height, m	10	10

	Level of control					
	SIP_1[c]	SIP_2[d]	AEL[e]	SIP_1[c]	SIP_2[d]	AEL[e]
Emissions, g/s	5.55	4.04	0.10	6.81	4.92	0.31
MGLC,[f] $\mu g/m^3$ @ 0.1 km	285 (54)	207 (39)	5.1 (1)	197 (28)	143 (21)	9.0 (1.3)
MGLC, $\mu g/m^3$ @ 0.3 km	180 (42)	131 (31)	3.2 (0.8)	116 (21)	84 (15)	5.3 (1)
MGLC, $\mu g/m^3$ @ 2 km	22 (5.4)	16 (3.9)	0.4 (0.1)	24 (5.3)	17 (3.8)	1.1 (0.05)
MGLC, $\mu g/m^3$ @ 20 km	1.2 (0.17)	0.9 (0.12)	0.02 (0)	1.2 (0.2)	0.9 (0.14)	0.05 (0)

[a] Based on 0.08 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ product.

[b] Based on 11.4 g/dry std. m^3 and 10% v moisture content.

[c] Based on least stringent state regulations.

[d] Based on most stringent state regulations.

[e] Based on AEL of 0.023 g/dry std. m^3.

[f] MGLC - maximum ground level concentration of particulate matter; 24-h average (annual mean).

significant. The estimated maximum ground level concentration (MGLC) of particulate matter for uncontrolled processes is given in Table 5-4 by linear extrapolation.

Table 5-4. ESTIMATED AIR IMPACTS OF UNCONTROLLED PROCESSES

Process	Capacity, Mg/h	(tons/h)	MGLC, μg/m³ 24-h avg	(annual mean)
Drying	45	(50)	2150	(288)
	272	(300)	4120	(365)
Calcining	18	(20)	1215	(120)
	63	(70)	1560	(94)
Grinding	45	(50)	2000	(380)
	136	(150)	3390	(490)

It is important to restate that SIP mass emission levels may not always be as stringent as opacity regulations, especially in smaller processes. If these processes were to meet opacity regulations by reducing particulate emissions, the source might well achieve NAAQS in the local environment. In this regard, the analysis of SIP levels is not entirely valid for all cases. Clear or near clear plume opacity is assumed for a dust loading of 0.12 to 0.23 g/m^3 (0.05 to 0.1 gr/dscf).[2] At these conditions, NAAQS can be achieved. On a plant-wide basis, the impact of the collective sources on the air quality appears to be less than the NAAQS.

5.3 WATER POLLUTION IMPACT

The application of air pollution control technology does not significantly affect wastewater volume or pollutant loadings. No wastewater is generated by fabric filters or ESP's. The wet scrubber is the only control device that generates wastewater. The major source of wastewater is the beneficiation process, which generates nearly 41.7 m^3/Mg of product (10^4 gal/ton).[3]

To consider the potential impact, a "worst-case" model plant was selected to maximize wastewater generation by air pollution controls. The model plant produces 90.7 Mg/h (100 tph) of calcined rock, which is ground in a 90.7 Mg/h (100 tph) grinding facility. Emissions from all operations are controlled by a wet collector with a liquid-to-gas ratio of 1.34 ℓ/m^3 (10 gal/10^3 acf). Inlet concentrations are assumed to be high at 11.4 g/dry std. m^3 (5 gr/dscf). Scrubbers operate at 95 percent collection efficiency.

The total wastewater generated by the wet scrubbers, assuming 90 percent recycle, is about 9.5 ℓ/s (150 gpm). The total wastewater generated by the beneficiation operation is about 1.053 m^3/s (16,700 gal/min). Thus, the additional volume contributed by the wet scrubbers constitutes an increase of less than 1 percent. If the wastewater is pumped directly to the tailings ponds from the scrubber without a retention tank (once-through water), the increase in the discharge volume to the ponds is about 10 percent.

Wastewaters from control operations are normally combined with other wastewaters prior to treatment, recycling, and/or discharge. Treatment of wastewaters from phosphate rock processing normally consists of gravity separation in ponds that also contain wastewaters from beneficiation and/or phosphoric acid production. Occasionally, the overflow from these ponds is treated by addition of flocculating agents and pH adjustment. Discharge of the overflow waters from these ponds is dependent upon a number of factors:

- the percent recycled
- rainfall, total and frequency
- surface runoff
- evaporative losses
- available pond acreage

In the western states, where evaporative losses are a major factor, the entire overflow from the ponds is usually recycled and accounts for 65 percent or greater of the process water. In the eastern states, evaporative losses normally do not offset the effect of precipitation. Hence, part of the overflow from the ponds is intermittently or continuously discharged to receiving bodies of water; the remaining portion, 60 to 90 percent, is recycled.[3]

Table 5-5 shows the chemical analysis of a typical phosphate rock product and the corresponding dust from the calcining operation. The quality of the wastewater discharged from a scrubber and the recirculation tanks is predicted from this information. Table 5-6 gives the predicted effluent quality for the model plant described above based on these chemical analyses. Since these concentrations are independent of the production capacity under the assumptions made, it is not likely that the solids content of any calciner scrubber effluent will exceed 5000 ppm (0.5% by wt.) or that grinder scrubber effluent will exceed 7500 ppm (0.75% by wt.). If wastewater is recirculated at a recycle rate of 90 percent and settling efficiency in the recirculation tank is maintained at 90 percent, outlet concentrations are nine times the inlet concentrations.

Table 5-5. CHEMICAL ANALYSIS OF PHOSPHATE ROCK ROCK PRODUCED AND DUST EMISSIONS FROM CALCINER CYCLONES[4]

(in percent by weight)

Component	Phosphate rock product	Dust from cyclones
Calcium (CaO)	45.5	18.3
Phosphorous (P_2O_5)	32.5	14.4
Silica (SiO_2)	11.0	35.5
Aluminum (Al_2O_3)	2.0	8.4
Iron (Fe_2O_3)	0.8	2.3
Magnesium (MgO)	0.7	0.1
Other	7.5	21.0

Effluent is discharged to the tailings pond directly from the scrubber or the recirculation tank. A high degree of solids removal (>90 percent) and dilution is achieved in these ponds. Pond effluent may require additional treatment prior to recycling to the beneficiation facility or discharge to surface waters.

No significant increase in the wastewater discharge volume and no increase in pollutants or contribution of a different pollutant are expected by the use of wet grinding techniques. No additional solid waste is generated. Effluent limitations established by EPA will require no discharge at all by 1980.

Table 5-6. PREDICTED EFFLUENT QUALITY FROM WET SCRUBBERS ON CALCINERS AND GRINDERS

	90.7 Mg/h (100 tons/h) Calciner		90.7 Mg/h (100 tons/h) Grinder	
Exhaust volume, m^3/s (acfm)[a]	63.25	(134,000)	7.55	(16,000)
Dust loading, g/dry std. m^3 (gr/dscf)	11.4	(5.0)	11.4	(5)
Emission rate, Mg/h (lb/h)[b]	1.46	(3214)	0.281	(620)
Solids collected, Mg/h (lb/h)[c]	1.39	(3054)	0.267	(589)
Raw wastewater flow, ℓ/s (gal/min)[d]	84.5	(1340)	10.09	(160)
Recirculation tank wastewater composition, ppm[e] by weight	Inlet[f]	Outlet[g]	Inlet[f]	Outlet[g]
Calcium (CaO)	830	7470	3350	30,200
Phosphorous (P_2O_5)	653	5880	2390	21,500
Silica (SiO_2)	1610	14,490	810	7290
Aluminum (Al_2O_3)	381	3430	147	1320
Iron (Fe_2O_3)	104	936	59	530
Magnesium (MgO)	45	405	51	460
Total suspended solids, ppm by weight	4560	41,000	7357	66,210

[a] Calciner exhaust flow is based on 0.51 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ (1000 scfm per tons/h); grinder exhaust flow is based on 0.08 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ (160 scfm/tph).

[b] Moisture content of exhaust assumed at 25% v for calciner and 10% v for grinder.

[c] Wet scrubber collection efficiency is 95 percent.

[d] Liquid-to-gas ratio is 1.34 ℓ/m^3 (10 gpm/10^3 acfm).

[e] Calculated from Table 5-5. Grinder dust emissions have the same composition as the product composition.

[f] Inlet to recirculation tank is the same as the outlet from the scrubber. If no recirculation is used, the inlet composition is the same as the discharge to the tailing pond.

[g] The outlet composition from the tank assumes 90 percent recycle and 90 percent settling efficiency. This stream would be discharged to the tailings pond.

5.4 SOLID WASTE IMPACT

It is not anticipated that air pollution control will have a significant incremental impact on the solid waste from phosphate rock processing. The major source of solid wastes is from the beneficiation of the ore. About 70 percent of the mined rock in Florida is wasted in beneficiation.[5] Solid wastes generated by air pollution control devices originate from drying, calcining, and grinding operations. Since dust collected by fabric filters on grinding and rock handling operations is recycled, it is not a source of solid waste.

The increase in solid waste volume contributed by emission control over that generated by beneficiation is illustrated in Table 5-7. A "worst-case" analysis is given to show the maximum expected impact. The "worst-case" assumes the extreme mass emission rate and the grinding of all dried and calcined rock.

Model Plant A consists of one 272 Mg/h (300 tons/h) dryer and two 136-Mg/h (150-tph) grinders, each controlled by wet collectors. Model Plant B consists of four 63.5 Mg/h (70-tons/h) calciners and two 136-Mg/h (150-tph) grinders, each controlled by wet collectors. The maximum incremental impact on solid waste generation is shown to be 0.44 percent (dry) for Model Plant A and 0.03 percent (dry) for Model Plant B.

Table 5-7. SUMMARY OF SOLID WASTE IMPACT FOR TWO WORST-CASE MODEL PLANTS

Control level	Solid wastes generated, Mg/yr (tons/h)[a]	
	Model Plant A[b]	Model Plant B[c]
SIP_1	20,330 (22,410)	35,810 (39,480)
SIP_2	20,510 (22,610)	36,090 (39,790)
AEL	20,790 (22,926)	36,440 (40,171)
Total solid wastes from beneficiation[d]	4,730,000 (5,210,000)	4,410,000 (4,860,000)
Percent increase by dry weight	< 0.44	< 0.83
Percent increase by total weight[e]	< 1.5	< 2.8

[a] These model plants operate at 85 percent of the annual capacity.

[b] Model plant A includes one 272 Mg/h (300 tons/h) dryer and two 136-Mg/h (150 tons/h) grinding systems.

[c] Model plant B includes four 63.5 Mg/h (70 tons/h) calciners and two 136 Mg/h (150 tons/h) grinders.

[d] Seventy percent of the processed ore is wasted in beneficiation.

[e] Assuming sludge from settling ponds is 30 percent solids.

Tables 5-8, 5-9, and 5-10 indicate the amount of dust (dry weight) collected by the control devices for each of three control levels for the drying, calcining, and grinding operations. A comparison between the two plants is given in Table 5-7.

Based on this analysis, solid waste impact from the application of air pollution control technology is small.

5.5 ENERGY IMPACT

Application of emission control technology to meet SIP_1, SIP_2, and AEL emission levels will not result in a significant energy impact. Energy impact is defined as the increase in energy required to operate air pollution control devices and related systems over the energy required for the operation itself (fuel oil, electricity, natural gas, etc.). Control systems use electrical energy. The corresponding increased consumption of fossil fuels at the power generation plant is estimated by assuming a 30 percent efficiency for power generation and transmission.

A dryer generating 0.23 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ (450 scfm per tons/h) requires an additional 14 MJ/Mg product (12,000 Btu/ton) of electrical energy to operate a venturi scrubber at a system pressure drop of 7.5 kPa (30 in. WG). A fabric filter system operating at 2.5 kPa (10 in. WG) requires an additional 4.7 MJ/Mg product (4000 Btu/ton) of

Table 5-8. SOLID WASTES GENERATED BY DRYER EMISSION CONTROLS

Production rate, Mg/h (tons/h)	45	(50)	272	(300)
Throughput rate, Mg/h (tons/h)[a]	51	(56)	302	(333)
Uncontrolled emission, Mg/h (lb/h)[b]	0.329	(723)	1.972	(4339)
SIP$_1$ dust collected, Mg/h (lb/h)[c]	0.307	(676)	1.944	(3396)
SIP$_2$ dust collected, Mg/h (lb/h)[d]	0.314	(690)	1.953	(4296)
AEL dust collected, Mg/h (lb/h)[e]	0.327	(719)	1.960	(4312)

[a] Assumed 10 percent weight loss during drying.

[b] Calculated at 0.23 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ (450 scfm per tons/h), 11.4 g/dry std. m^3 (5 gr/dscf), and 25% v moisture.

[c] Based on Florida regulation for particulate emissions.

[d] Based on regulations for all states except Florida.

[e] Based on AEL of 0.070 g/dry std. m^3 (0.031 gr/dscf).

Table 5-9. SOLID WASTES GENERATED BY CALCINER EMISSION CONTROLS

Production rate, Mg/h (tons/h)	18 (20)	63.5 (70)
Throughput rate, Mg/h (tons/h)[a]	20 (22)	71 (78)
Uncontrolled emissions, Mg/h (lb/h)[b]	0.291 (642)	1.021 (2250)
SIP_1 dust collected, Mg/h (lb/h)[c]	0.277 (610)	1.005 (2215)
SIP_2 dust collected, Mg/h (lb/h)[d]	0.280 (618)	1.011 (2228)
AEL dust collected, Mg/h (lb/h)[e]	0.289 (638)	1.014 (2236)

[a] Assumed 10 percent weight loss during calcining.

[b] Calculated at 0.52 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ (1000 scfm per tons/h) 11.4 g/dry std. m^3 (5 gr/dscf), and 25% v moisture.

[c] Based on Florida emission regulations.

[d] Based on regulations for all states except Florida.

[e] Based on AEL of 0.070 g/dry std. m^3 (0.031 gr/dscf).

Table 5-10. SOLID WASTES GENERATED BY GRINDER EMISSION CONTROLS

Production rate, Mg/h (tons/h)	45 (50)	136 (150)
Throughput rate, Mg/h (tons/h)	45 (50)	136 (150)
Uncontrolled emissions, Mg/h (lb/h)[a]	0.140 (309)	0.420 (926)
SIP_1 dust collected, Mg/h (lb/h)[b]	0.120 (265)	0.396 (872)
SIP_2 dust collected, Mg/h (lb/h)[c]	0.126 (277)	0.403 (888)
AEL dust collected, Mg/h (lb/h)[d]	0.140 (308)	0.419 (923)

[a] Calculated from 0.08 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ (160 scfm per tons/h), 11.4 g/dry std. m^3 (5 gr/dscf), and 10% v moisture.

[b] Based on Florida emission regulations.

[c] Based on regulations from all other states except Florida.

[d] Based on AEL of 0.030 g/dry std. m^3 (0.013 gr/dscf).

electrical energy, and an electrostatic precipitator (ESP) operating at a pressure drop of 1.3 kPa (5 in. WG) requires an additional 2.6 MJ/Mg (2200 Btu/ton).

A calciner generating 0.51 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ (1000 scfm per tons/h) requires an additional 31 MJ/Mg product (26,700 Btu/ton) of electrical energy for a venturi scrubber, 10.4 MJ/Mg (8890 Btu/ton) for a fabric filter, and 5.8 MJ/Mg (4890 Btu/ton) for an ESP. These systems operate at the same pressure drop as for the dryer applications.

A grinder generating 0.08 wet std. $m^3 \cdot s^{-1}/Mg \cdot h^{-1}$ (160 scfm per tons/h) requires an additional 3.8 MJ/Mg product (3200 Btu/ton) of electrical energy for a venturi scrubber and 1.3 MJ/Mg (1100 Btu/ton) for a fabric filter.

The above energy requirements were calculated from energy balances based on flow rate and system pressure drop. Table 5-11 shows the energy data reported by the industry.

As shown in Table 5-12, the overall increase in fossil fuel consumption resulting from emission control technology is substantial, up to 17 percent by high-energy scrubbing of calciner emissions and up to 12 percent by high-energy scrubbing of dryer emissions. The increase in energy requirements for a fabric filter and an ESP would be 33 and 80 percent lower, respectively. The incremental impact (additional increase in energy consumption) of more stringent

Table 5-11. ENERGY CONSUMPTION FOR PHOSPHATE ROCK PROCESSES AND ASSOCIATED CONTROL DEVICES[1]

Process	Process energy, MJ/Mg (10^3 Btu/ton)[a]	Control device[b]	Energy required by control device, MJ/Mg (Btu/ton)[a]	Increase in equivalent fossil fuel consumption, percent[c]
Rotary dryer	292 (251)	IS + ESP	6.6 (5690)	7.7
Fluid bed dryer	324 (279)	IS + ESP	10.3 (8900)	10.8
Fluid bed dryer	515 (443)	CS	3.3 (2810)	2.1
Fluid bed dryer	460 (395)	Unknown	Unknown	Unknown
Rotary and fluid bed dryer	509 (438)	CS	3.6 (3130)	2.4
Rotary dryer	354 (305)	IS	9.6 (8310)	9
Rotary dryer	326 (281)	VS	23.9 (20,600)	24
Roller mill	76 (66)	FF	1.7 (1500)	7.7
Ball mill	65 (56)	FF	1.4 (1280)	7.7
Ball mill	44 (38)	Unknown	Unknown	Unknown
Roller mill	138 (119)	VS	4.3 (1300)	10.3

[a] Reported by the industry.

[b] Key: IS, impingement scrubber; ESP, electrostatic precipitator; CS, cyclonic scrubber; VS, venturi scrubber; FF, fabric filter.

[c] Assuming 30% power transmission and generation efficiency.

Table 5-12. ENERGY IMPACT OF APPLYING EMISSION CONTROL TECHNOLOGY

Process	Process energy[a] MJ/Mg (Btu/ton)	Increased equivalent fossil fuel consumption, %[b]		
		VS	FF	ESP
Drying[c]	397 (341,000)	12	3.9	2.1
Calcining[c]	611 (525,000)[e]	17	8.5	4.7
Grinding[d]	270 (233,000)	4.6	1.6	-

[a] Averages of energy requirements reported by the industry; Table 5-11.

[b] Based on calculated energy requirements and 30% generating and transmission efficiency; Key: VS, venturi scrubber; FF, fabric filter; ESP, electrostatic precipitator.

[c] Practically all energy in the form of fossil fuel.

[d] All energy used in grinding is electrical. These numbers represent equivalent fossil fuel consumption.

[e] Estimated in reference 1.

control called for by AEL or new state regulations over SIP controls may be considerably less. If more stringent regulations require an additional 2.5 kPa (10 in. WG) pressure drop across a venturi scrubber, the incremental impact will be 4 percent additional fossil fuel.

Operations presently controlled by fabric filters or ESP's have little or no incremental energy impact because efficiency for these devices is independent of the system pressure drop. Energy required by ESP plates is about 0.03 kW/m^2 plate area (0.003 kW/ft^2) in addition to the power required by the fan system. However, the additional energy demand by application of high-energy scrubbers can be significant.

By replacing dry grinding with wet grinding systems where feasible, the dryer and its fuel consumption are eliminated. This savings is estimated to be 397 MJ/Mg (341,000 Btu/ton), equivalent to about 10 ℓ of oil/Mg rock (2.4 gal oil/ton).

In summary, the incremental energy impact is small for operating control equipment to meet more stringent emission regulations than existing SIP levels.

5.6 RADIATION IMPACT

The pollutants in plant wastewaters can include not only the common ones such as suspended solids, high acidity, fluorides, and phosphates, but also radiochemical pollutants (e.g., radium-226).[6] The source of the radiochemical pollution problem is the widely acknowledged presence of uranium in phosphate rock in the range of 50 to 200 g/Mg (0.1 to 0.4 lb/ton) of rock. Discharge or leakage from the holding ponds described in subsection 5.3 could therefore constitute a major pollution problem to the aquatic environment of receiving streams. Also, seepage of these waters into aquifers could contaminate drinking waters. Sampling of recycled water reportedly has indicated that such waters contain 90 to 100 picocuries per liter of radiochemical pollutants.[6] This is more than 3 times the Atomic Energy Commission (AEC) standard for release to an unrestricted environment within an AEC licensed plant, and 30 times the maximum permissible concentration for water.

Sizable quantities of radioactive particles have also been found in solid wastes discarded from phosphate rock plants. One analysis of radiochemical pollutants in phosphate rock slimes (a by-product of beneficiation) revealed radium-226, uranium, and thorium in quantities of 45, 89, and 53 picocuries per gram, respectively.[7] Soil throughout the United States typically contains between 0.15 and 2.8 picocuries of radium-226 per gram.[8]

Recent attention has been given to the exposure to radioactivity of persons living in structures built on reclaimed phosphate land. One study indicated that exposure of these inhabitants was up to 50 times the normal background level of radiation.[8] This exposure is about 2.5 times greater than the present Federal guideline for maximum exposure of uranium miners.[9] These recent findings, part of an ongoing EPA study, will most likely result in the establishment of guidelines for disposal of radioactive wastes.

Air emission standards will not cause a significant increase in radiochemical pollutants discharged from the plants by aqueous discharge and sludge disposal. As explained in subsection 5.3, water used for emission control devices is negligible compared with total water usage at a phosphate rock plant. The additional amount of particulate collected and ultimately disposed as solid waste also will be negligible. In fact, particulate collected by dry collection devices such as baghouses will have a positive impact on radiochemical pollution since it can be returned to product inventories rather than discarded.

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8. Environmental Protection Agency. Preliminary Findings Radon Daughter Levels in Structures Constructed on Reclaimed Florida Phosphate Land. EPA Technical Note No. ORP/CSD-75-4. September 1975. p. 6.

9. Ibid. p. 14.

6.0 EMISSION MEASUREMENT AND CONTINUOUS MONITORING

6.1 EMISSION MEASUREMENT METHODS

The Environmental Protection Agency has successfully used Reference Methods 1 through 5 to measure particulate emissions from the phosphate rock processing industry, applying these methods as described in Appendix A of CFR 40 Part 60 and published in the Federal Register (December 23, 1971, and October 23, 1974).

The particulate mass catches obtained from the process emission streams were relatively low, especially when emissions were controlled by fabric filters. The mass catch amounts ranged from about 12 mg (0.19 gr) to over 300 mg (4.63 gr). When concentrations were particulary low, some tests had to be extended to more than 3 hours to obtain accurately measurable catches. In-house EPA tests show that an accuracy of ± 10 percent can be obtained with a minimum catch of 25 mg (0.39 gr).[1] Inaccuracies at this level and below tend to bias the sample on the high side of the measurement; that is, the measurement will indicate somewhat more mass than is actually collected by the impingers.[1]

Visible emission readings are difficult to measure because of the high moisture content of the scrubber exhausts from several of the dryer and calciner exhausts. Opacity readings are usually made at the leading edge of the steam plume.

6.2 CONTINUOUS MONITORING

The EPA performance standards for opacity monitors are contained in Appendix B of 40 CFR Part 60 (Federal Register, September 11, 1974). These monitors are especially useful for measuring opacity when the exhaust gases are above the dew point and formation of water vapor plume makes measurement difficult by visual methods.

Effluent gases from phosphate rock processes are not excessively hot [less than 120°C (250°F)], but they sometimes contain fluorides, which react with water to form acids that etch glass materials. Glass lenses on opacity monitoring equipment should either be protected from fluoride deposits or replaced with material that is not subject to etching.

Equipment and installation costs for an opacity monitor are estimated to be $18,000 to $20,000; annual operating costs, including data recording and reduction, are estimated to be $8000 to $9000.[1]

6.3 PERFORMANCE TEST METHODS[1]

The performance test method recommended for measuring particulate matter is EPA Method 5. Because of the construction of some control equipment, special stack extensions are sometimes required to obtain acceptable sampling conditions. The recommended minimum sample volume is 4.5 dry std. m^3 (160 dscf). Because of the lower particulate concentrations in the stack gases from processes controlled by fabric filters, longer sampling times and larger sample volumes are required to produce acceptable data. High-volume sampling trains, which are commercially available and conform to Method 5 specifications, are capable of obtaining the minimum sample volume in tests of shorter duration.

Sampling cost for a test consisting of three particulate runs is estimated to be about $5000 to $9000. This estimate includes $2000 to $4000 for sampling site modifications such as ports, scaffolding, ladders, and extensions.

Reference Method 9 is recommended for determining visible emissions.

REFERENCE

1. Standards Support and Environmental Impact Statement. An Investigation of the Best Systems of Emission Reduction for the Phosphate Rock Processing Industry. Draft. U.S. Environmental Protection Agency. OAQPS, ESED. Research Triangle Park, North Carolina. February 1976.

7.0 ENFORCEMENT ASPECTS

In setting an emission limitation, the aspects of enforcing that limitation must be considered. This section discusses alternative regulations and enforcement aspects of these regulations.

7.1 REGULATIONS

Applicable source emission limitations are of three types: existing state source regulations, state new source regulations or performance standards, and alternative emission levels that might be imposed by future legislation. The applicability of state regulations is determined by the respective SIP and the definition of a "new, modified, and/or reconstructed source." Appendix B discusses regulations in more detail, and Appendix C presents Florida regulations as an example of state regulations. No Federal New Source Performance Standards have been promulgated for this industry.

7.1.1 State New Source Regulations

Although no state has specifically set New Source Performance Standards for phosphate rock processing facilities, opacity and mass emissions will generally be more stringent for new facilities than for existing sources. Figure 7-1 shows state new source regulations for mass emissions. Table 7-1 presents state opacity regulations for new and existing sources compared with opacity limits designated by an alternative emission level (AEL).

7.2 FORMAT OF EMISSION STANDARDS

A variety of formats may be used to write standards governing how emission sources in the phosphate rock industry will be controlled. Possible formats for each potential source include mass per unit production [g/kg product (lb/ton)], mass per unit feed [g/kg feed (lb/ton)], mass per unit heat input [g/J (lb/10^6 Btu)], concentration [g/dry std. m^3 (gr/dscf)], mass rate [kg/h (lb/h)], equipment specifications, required maintenance procedures, etc. These different formats and their application to the processes under consideration are discussed below.

7.2.1 Dryers

7.2.1.1 Mass Rate per Unit Feed or Production--

Dryers are designed for a fixed moisture removal rate, which is based primarily on heat input. The rock feed rate is therefore a function of its moisture content and the type of rock. It can vary up to 100 percent for a given unit operating at maximum capacity. A standard based on a format of mass rate per unit of feed or production [g/kg

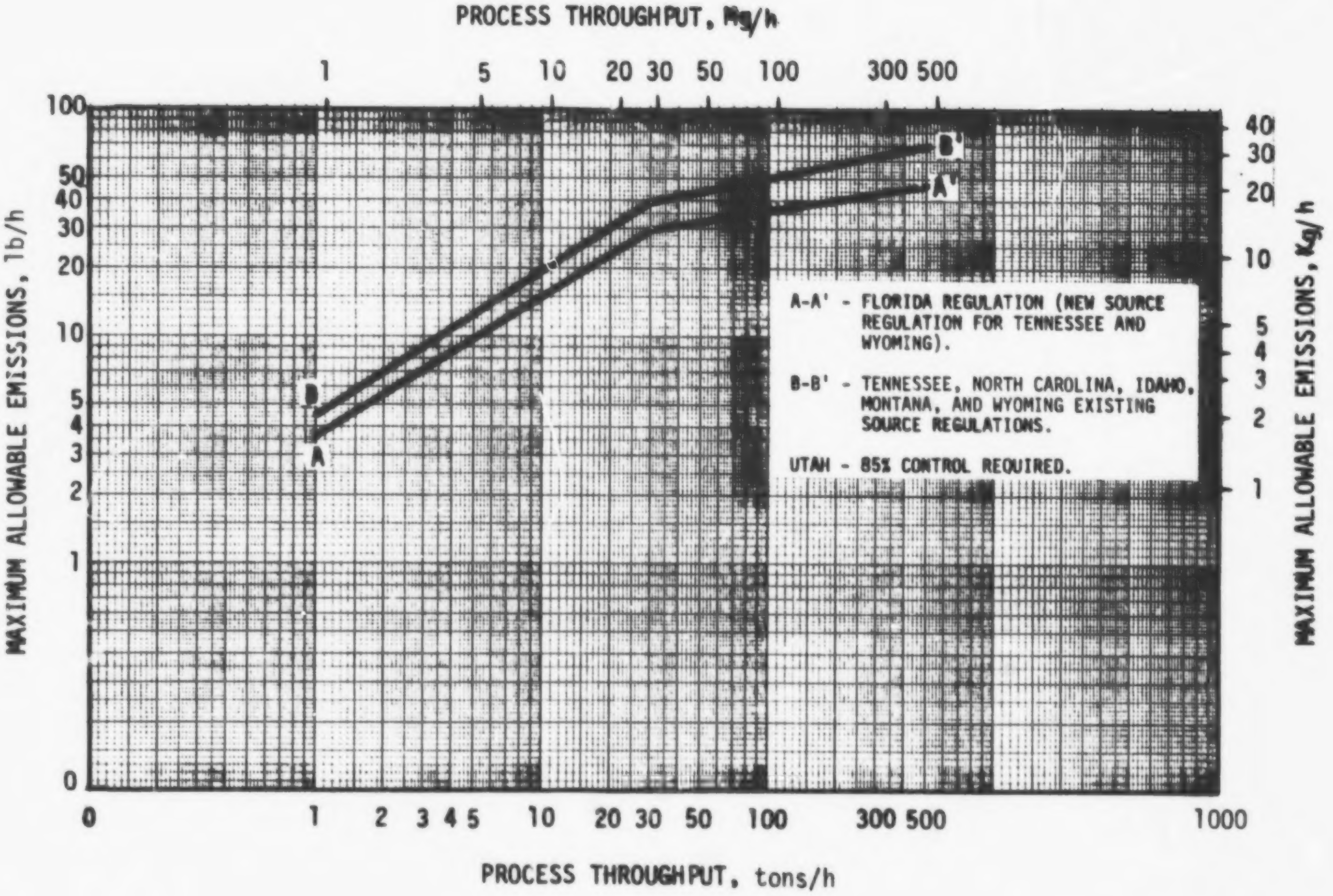


Figure 7-1. State mass emission limitations for new and existing sources.[2]

Table 7-1. OPACITY REGULATIONS FOR VARIOUS JURISDICTIONS

Jurisdiction	Opacity limitation, %
Alternative emission levels[a]	
° Drying and calcining	<10
° Grinding	< 5
° Rock conveying	< 5
Florida	<20
Montana	40
Utah	40
North Carolina	40[b]
Tennessee	40[b]
Idaho	40[b]
Wyoming	40[b]

[a] EPA Method 9. 6-minute averages.

[b] Twenty percent opacity limitation for new sources per SIP definition of new source.

(lb/ton)] would therefore penalize the operator when he is processing an unusually moist feed, since the residence time for the material would be longer and attrition of the rock would be greater than when the rock is less moist and passes through the dryer quickly. The reverse would be true (the standard would be unduely lenient) for an operator drying rock with a low moisture content. The effect of the moisture in the rock on suppression of emissions is not known, but is not believed to be great enough to cancel the effect of greater residence time on emissions.

7.2.1.2 Mass per Unit Heat Input--

A standard based on mass per unit heat input [g/J (lb/ 10^6 Btu)] would penalize the operator when he processes very dry rock because the amount of heat applied per ton of rock (i.e., the denominator of the standard units) would be unusually small.

7.2.1.3 Concentration and Mass Rate--

Standard formats of concentration [g/dry std. m^3 (gr/dscf)] and mass rate [kg/h (lb/h)] would provide the same degree of fairness for a given dryer over a given period of time, since concentration relates mass emissions to gas volume, and mass rate relates mass emissions to time. The allowable mass rate must be specific to a certain production rate since, as production increases, gas volume and particulate emissions will increase. Concentrations of emissions are somewhat independent of production rate.

Circumvention of a concentration standard is possible by dilution of the gas stream. This is unlikely, however, since the size and operating costs of the control device are functions of the volume of gas treated. Dilution of the gas stream after the control device can be specifically disallowed by the wording of the regulations. An example of such wording is found in §60.12 of the General Provisions of 40 CFR Part 60.

To develop a standard based on mass per unit time (kg/h), emissions should be investigated from a number of different sizes of dryers because larger units will, of course, have greater emission potential than smaller ones.

7.2.1.4 Equipment Specifications--

Specification of the control equipment to be used might be a viable option for control agencies whose funds for performance tests are limited or nonexistant. A major disadvantage of this kind of standard is that the operator has little incentive to keep the control system operating at peak performance levels. Required maintenance programs could accompany the equipment specification, but the burden of proving inadequate maintenance would be on the control agency. Another disadvantage is the lack of flexibility it gives the operator in choosing the control system he prefers.

7.2.1.5 Visible Emissions--

Visible emission standards also have the advantage of being inexpensive to administer. The major disadvantages of visible emission standards are the decreased enforcement potential at night and during adverse atmospheric conditions (i.e., fog, rain, overcast sky), and the inability to relate plume opacity to actual mass emissions. Visible emission standards are also open to the charge that enforcement is too subjective, and water vapor in the plume can make observations difficult.

The Environmental Protection Agency has frequently promulgated visible emission standards to accompany regulations of mass emissions. Such an arrangement allows the operator to install control equipment designed to meet the mass emission rate. Then, if the control system fails (as indicated by visible emissions), the control agency has a legal basis for requiring repairs without having to perform an expensive mass emission measurement.

7.2.2 Calciners

Considerations for formats for standards to apply to calciner emissions are the same as those discussed for dryers.

7.2.3 Grinders

A format relating mass emissions to unit heat input is obviously not applicable to standards for grinders. With that exception, the pros and cons of formats for standards for grinders are the same as those discussed for dryers. However, an additional consideration is necessary when evaluating a format to apply to standards for existing grinders. Neither feed nor production rates are typically measured at grinders. When the material into or out of a grinder is measured, the method is usually crude, intended only to estimate the flow of material. One plant tested by EPA measures the depth of rock in the ground rock silo at the end of a shift. That information, coupled with measurements of feed to the silo and from the silo to subsequent processes, permits an estimation of the grinding rate. Another plant measures, with a ruler, the height of rock at the center of a moving conveyor belt. The belt speed is then measured to obtain production rate.

Because of the lack of accurate flow measuring capabilities at currently operating grinders, the standard for grinders should not have production or feed rate as an integral part of the format unless there is also a requirement for the affected plant to institute an accurate flow measurement technique. There are no technical reasons why rock flow into or out of a grinder cannot be measured accurately.

7.2.4 Ground-rock Transfer Systems

As explained in Chapter 2, there are several kinds of ground-rock transfer systems. The type of system used will often limit the choices of formats for a standard. If an enclosed screw conveyor is used, the only potential sources of emissions are from the conveyor housing or the silo fed by the conveyor. Formats for this type of system would be limited to a measurement of visible emissions from the conveyor and/or the silo. The silo will be closed to protect the ground rock from the weather, but may have a breathing port to equalize pressure inside the silo during loading and unloading of the ground rock. The breathing port could be ducted to a control device, in which case the device could be made subject to a standard with one of the formats discussed for dryers (except the one relating emissions to heat input). Because materials flowing through the silo usually are not measured, one of the formats that does not rely on such a measurement would be desirable.

The most common ground-rock transfer systems are those that use pressurized air to move the rock, such as the dust pump (the most common system) or the air slide. With these systems, there is always an air discharge, usually at the receiving silo. This discharge is usually controlled to prevent product loss from the dust-laden air stream. Emissions from the control device are thus amenable to regulation using one of the formats discussed for dryers (except the one relating emissions to heat input). Materials flow, however, is typically not measured.

7.3 ENFORCING REGULATIONS[2]

The enforcement aspects of the standards and regulations just discussed are given in this section.

7.3.1 Dryers

Factors affecting the level of uncontrolled emissions from phosphate rock dryers include the design and operation of the dryer and the type of rock being dried. The effect of process design and operation on uncontrolled emissions is discussed in Chapter 2. The operator usually has little control over the design of the dryer after it is installed, and operation during a compliance test should not differ from the way the process is normally operated. The compliance test should be performed while the dryer is operating at the maximum production rate at which it is expected to run in the future, which may be greater than design parameters indicate. As stated in the facility descriptions in Appendix A, dryers are designed for a certain degree of moisture removal, and production at this moisture removal rate will be a function of the characteristics of the feed to the dryer. Generally, production throughput at a constant moisture-removal rate will be greater for small, dry feed than for large, wet feed. The enforcement official should therefore be concerned with the heat input (fuel addition rate) to the dryer, production throughput, and type of feed. Some dryers are designed to burn more than one kind of fuel (i.e., natural gas or fuel oil). In these cases, emissions from the dryer should be sampled while the dryer is burning the dirtiest fuel it will be burning.

The type of rock being processed by the dryer may affect emissions from some dryers processing rock from the Florida deposits. The Florida rock falls into two classifications, pebble rock and concentrates. Most operators indicate that they experience greater particulate emissions when drying pebble rock than when drying concentrates because the pebble rock goes through fewer washings in the beneficiation process (see Chapter 2), which causes it to have more clay adhering to its surface. Attrition in the dryer causes submicron-sized clay particles to be sloughed off, resulting in greater emissions to the control system. Though data comparing emissions while drying pebble rock with emissions while drying non pebble rock are not available, this appears to be a valid claim. The EPA performance tests were conducted while at least half of the rock being processed was pebble rock.

7.3.2 Calciners

The enforcement aspects for calciners are essentially the same as those presented for dryers. The only noteworthy difference is that is is unlikely that any units will be built to calcine Florida rock, so the possibility of processing pebble rock in the calciner need not concern the enforcement official.

7.3.4 Grinders

Phosphate rock grinders are of two basic designs: ball mills and roller mills. Ball mills are usually ducted to a single control device; however, roller mills are frequently operated in parallel, with several ducted to one control device. Therefore, it is incumbent on the enforcement official to be certain that all mills ducted to the control device are operating during the compliance tests. Types of raw materials do not affect emissions from phosphate rock grinders.

Factors that affect production rate from phosphate rock grinders are the mesh size (fineness) of the grind and the design of the grinder. Generally, emissions per ton of production will increase as the rock is ground to smaller mesh sizes. To increase the fineness of the grind, the operator must increase the residence time of the rock in the grinder, biasing the particle size distribution toward the smaller sizes. However, the process that will utlimately use the ground rock has been designed to accept a certain size rock, typically 60 percent through 200 mesh, and operates most efficiently with that size. Therefore, fineness of the grind is not generally a parameter that the operator changes frequently. As with dryers and calciners, production throughput of grinders is incidental to other considerations. Production tonnage decreases as the mesh size being produced gets smaller. Once the product size is set, the operator usually monitors the amperage of the mill motor and/or mill fan and runs the grinding mill at the maximum production rate possible without damaging the equipment. The enforcement official should obtain these operating limitations from previous operating data (usually available from past log sheets) or, if necessary, from design data.

7.3.5 Ground-rock Handling Systems

If a ground-rock handling standard only regulates visible emissions, the performance test should be performed only during clear days when visible emissions can be determined accurately. Also, because the ground-rock handling system usually operates intermittently, the performance test must be scheduled when the system will be operated for the duration of the observations.

REFERENCES

1. Memorandum to Don R. Goodwin, Director of Emission Standards and Engineering Division, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, from Chiefs of Industrial Studies Branch and Standards and Cost Analysis Branch. Subject: Recommended Standards of Performance for the Phosphate Rock Processing Industry. February 27, 1976.

2. Standards Support and Environmental Impact Statement. An Investigation of the Best Systems of Emission Reduction for the Phosphate Rock Processing Industry. Draft. OAQPS, ESED. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. February 1976.

8.0 REGULATORY OPTIONS

This chapter presents a discussion of the various regulatory options available for the control of particulate emissions from phosphate rock processing plants. Regulatory options are discussed in terms of applicable control technology; new versus existing plants; environmental, energy, and cost impacts; emissions limits; format of emission limits or standards; and process modifications.

8.1 CONTROL TECHNOLOGY AND IMPACTS

Alternative control technologies are fabric filtration, wet scrubbing, and electrostatic precipitation. Electrostatic precipitators are not used in grinder operations and fabric filters are not being used on calciners or dryers; however, these technologies are believed to be feasible. Wet grinding is considered a feasible control technology by process change if the rock is to be used in wet process phosphoric acid plants.

Table 8-1 summarizes the estimated energy, environmental and cost impacts at various levels of emission control. Air, water, solid waste, energy and cost impacts are discussed in Sections 8.1.1 through 8.1.5; however, it can be generally stated that fabric filtration can achieve highest emission reduction for the least cost and generates no wastewater. There are no differences in energy, environmental, and cost impacts

Table 8-1. SUMMARY OF IMPACTS OF APPLYING ALTERNATIVE CONTROL TECHNOLOGIES

Systems		Impacts	AEL[a]					SIP$_2$[b]					SIP$_1$[c]				
			Air[d]	Water[e]	Solid Waste[f]	Energy[g]	Annual cost[h]	Air[d]	Water[e]	Solid Waste[f]	Energy[g]	Annual cost[h]	Air[d]	Water[e]	Solid waste[f]	Energy[g]	Annual cost[h]
Dryer	45 Mg/h (50 tons/h)	Fabric filter	13 (1.8)	0.0	0.19	3.9	90	13 (1.8)	0.0	0.19	3.9	90	13 (1.8)	0.0	0.19	3.9	90
		Scrubber	13 (1.8)	3.7	0.19	12.	142	98 (13)	3.7	0.18	8.0	124	140 (19)	3.7	0.18	6.0	117
		ESP[i]	13 (1.8)	0.0	0.19	2.1	334	98 (13)	0.0	0.18	2.1	278	140 (19)	0.0	0.18	2.1	269
	272 Mg/h (300 tons/h)	Fabric filter	26 (2.3)	0.0	0.19	3.9	369	26 (2.3)	0.0	0.19	3.9	369	26 (2.3)	0.0	0.19	3.9	369
		Scrubber	26 (2.3)	3.7	0.19	12.	598	42 (3.7)	3.7	0.19	8.0	494	61 (5.4)	3.7	0.19	6.0	442
		ESP[i]	26 (2.3)	0.0	0.19	2.1	711	42 (3.7)	0.0	0.15	2.1	689	61 (5.4)	0.0	0.15	2.1	668
Calciner	18 Mg/h (20 tons/h)	Fabric filter	13 (1.7)	0.0	0.44	8.5	80	13 (1.7)	0.0	0.44	8.5	80	13 (1.7)	0.0	0.44	8.5	80
		Scrubber	13 (1.7)	8.0	0.44	17.	130	73 (10)	8.0	0.44	11.	115	96 (13)	8.0	0.44	8.5	100
		ESP[i]	13 (1.7)	0.0	0.44	4.7	320	73 (10)	0.0	0.44	4.7	270	96 (13)	0.0	0.44	4.7	260
	63 Mg/h (70 tons/h)	Fabric filter	21 (1.8)	0.0	0.43	8.5	210	21 (1.8)	0.0	0.43	8.5	210	21 (1.8)	0.0	0.43	8.5	210
		Scrubber	21 (1.8)	8.0	0.43	17.	330	51 (4.4)	8.0	0.43	11.	280	71 (6.1)	8.0	0.43	8.5	250
		ESP[i]	21 (1.8)	0.0	0.43	4.7	530	51 (4.4)	0.0	0.43	4.7	485	71 (6.1)	0.0	0.43	4.7	465
Grinder	45 Mg/h (50 tons/h)	Fabric filter[j]	5.1 (1.0)	0.0	0.00	1.6	20	5.1 (1.0)	0.0	0.00	1.6	20	5.1 (1.0)	0.0	0.00	1.6	20
		Scrubber	5.1 (1.0)	1.0	0.09	4.6	60	207 (39)	1.0	0.09	3.1	57	285 (54)	1.0	0.09	2.3	54
	136 Mg/h (150 tons/h)	Fabric filter[j]	9.0 (1.3)	0.0	0.00	1.6	34	9.0 (1.3)	0.0	0.00	1.6	34	9.0 (1.3)	0.0	0.00	1.6	34
		Scrubber	9.0 (1.3)	1.0	0.09	4.6	161	143 (21)	1.0	0.09	3.1	151	197 (28)	1.0	0.09	2.3	146

[a] AEL = alternative emission levels; 0.07 g/dry std. m^3 (0.03 gr/dscf) outlet for dryers and calciners; 0.023 g/m^3 (0.01 gr/dscf) outlet for grinders.

[b] SIP_2 = most stringent state regulation; see Appendix B.

[c] SIP_1 = least stringent state regulation; see Appendix B.

[d] Expressed as maximum ground level concentration, $\mu g/m^3$; 24-hour max. (annual mean). Fabric filter is assumed to reduce emissions to AEL regardless of applicable regulation. See Tables 5-1, 5-2, and 5-3.

[e] Expressed as percent increase in total plant wastewater volume, assuming no recycle of scrubber water.

[f] Expressed as maximum expected percent increase in total plant solid waste generation. See Tables 5-7, 5-8, and 5-9.

[g] Expressed as percent increase in equivalent fossil fuel energy over process energy requirements. See Section 5.5.

[h] Expressed in thousands of 4th quarter 1977 dollars. Retrofitted carbon steel systems. See Chapter 4.0.

[i] A wet-type ESP generates a wastewater stream. The water pollution impact is estimated to be approximately that of a wet scrubber.

[j] Collected dust is recycled and product recovery credits are included in annual costs.

for fabric filtration for a specific operation regardless of required emission level. Despite the advantages of lower cost and environmental impacts for fabric filters, wet scrubbers are the most popular control method used by the industry for dryers and calciners.

For complete plants including beneficiation, there is no potential for significantly increased solid waste or water pollution impacts, regardless of control technology, emission level, or plant size. This is because of the relatively large amounts of wastewater and solid waste generated by beneficiation.

The energy impact from the use of wet scrubbers is considerably more than for ESP's or fabric filters, especially at the more stringent control levels.

The cost of applying control technology is much higher for ESP's than for fabric filters or wet scrubbers.

Fabric filters are the most popular and least expensive control method for grinder emissions. The primary advantages of dry collection are that it provides excellent control of air emissions, has no attendant aqueous effluents, and facilitates recovery of valuable product.

8.1.1 Air Quality

Emissions and air impacts are significantly different for the AEL and SIP control levels, especially on the smaller capacity units. Air emissions from dryers and calciners can be up to about 10 times higher at the SIP level compared to

AEL control. The emissions from small grinders at the SIP control level are about 60 times those for the AEL control. This comparison for the large grinder is a factor of 20. The reason for the widespread difference in emission and air impact is because SIP levels are based on rates of mass emissions which yield relatively high outlet grain loadings of 2.3 g/dry std. m^3 (1.0 gr/dscf), whereas AEL control is based directly on relatively low concentration, i.e., 0.07 g/dry std. m^3 (0.03 gr/dscf).

As shown on Table 8-1, the system with the least air impact would be any one that operates with emissions equivalent the AEL. If fabric filtration is chosen to achieve this emission limitation, cost and water impacts will be less than the cost and water impacts from scrubbers or ESP's. Energy requirements for a fabric filtration system are greater than those for an ESP. Solid wastes will be the same regardless of the control device chosen to achieve the AEL for a given process.

If an operator chooses a high-efficiency scrubber to achieve the AEL, he will do so at the expense of greater costs resulting from the high energy requirements necessary to maintain a sufficient pressure drop sufficient to attain the low emission rate. In addition, aqueous effluents generated by the scrubber will have to be piped to a receiving pond or treated before discharge to public waters.

Negative aspects of selecting a system with the least impact on air quality can be increased solid wastes, increased water effluents (unless a fabric filter or dry ESP is chosen), higher energy requirements, and greater cost. Solid wastes attendant to achieving the AEL increase from 0 to 117 percent over the SIP_1 level. Water effluent volume from venturi scrubbers is the same for all levels of control for a given operation. Increased energy required to achieve AEL range from 0 to 100 percent over that required to achieve the SIP_1 level, and annual costs increases range from 0 to 35 percent, depending on the control device chosen.

8.1.2 Water Pollution Impact

The control systems with the least water pollution impact are the fabric filter and dry ESP because no water is discharged from these units. The use of an ESP or fabric filter will also result in an energy savings of 40 to 65 percent over the energy required by wet scrubbers at the SIP_1 level and 45 to 80 percent at AEL control. Air and solid waste impacts are identical at the same control level for each control option and process. Costs of the fabric filter do not increase with control level; costs of the ESP increase from 20 to 35 percent from SIP_1 to AEL control.

As stated on page 8-3, for complete plants that include beneficiation the small increase in water pollution impacts (regardless of control technology, emission level, or plant size) is due to the relatively large amount of wastewater generated by beneficiation.

8.1.3 Solid Waste Impact

When fabric filters are used to control emissions from phosphate rock grinders, no solid waste is generated because the collected dust is recycled, and no wastewater is discharged. This is one reason why the annual cost of using fabric filters on grinders is 20 to 35 percent lower than when wet scrubbers are used.

The solid waste impacts increase about 0.2 percent for dryers and 0.4 percent for calciners, regardless of size, control device, or control level. The solid waste impact is very small for any regulatory option since relatively large amounts of solid waste are generated by beneficiation.

8.1.4 Energy Impact

Use of an ESP will decrease energy demand by 50 to 80 percent below that required by scrubbers at AEL control and 45 to 65 percent at SIP_1, depending on process size. Fabric filters require 85 percent more energy than the ESP's. However, annual costs for electrostatic precipitators are from 80 to 270 percent more than fabric filters and 18 to 160 percent more than scrubbers, depending on process, size, and control level. Also, the use of ESP's to attain SIP levels results in the sacrifice of the incremental emission reduction achieved by fabric filters. Emissions are about 2 to 10 times higher with ESP's than with fabric filters, depending on the process and process size.

The control system with the least energy impact for the grinding operation is the fabric filter, which requires 30 to 65 percent less energy than scrubbers. As previously stated, no wastewater or solid waste is generated, and the costs are 37 to 79 percent of those for scrubbers. Emissions are 20 to 60 times greater when using scrubbers than when using fabric filters at SIP_1, depending upon the size.

8.1.5 Cost Impact

The least costly control system for each of the processes is the fabric filter. The annual cost of other control systems ranges from 1.2 (large calciner/scrubber/SIP_1) to 4.7 times (large grinder/ scrubber/AEL) the annual cost of fabric filters, even though fabric filters consume almost twice as much energy as ESP's. As stated before, no wastewater is generated, and the solid waste impact from dryer and calciner fabric filters is no more than that for scrubbers and ESP's. A major advantage of fabric filters on the grinder is the ability to recycle the dust that is collected.

8.2 NEW VERSUS EXISTING PLANTS

Regulatory options specified for each process would not be different for new versus existing plants. There are usually no technical or physical constraints that would preclude the installation of a certain control device on an existing facility if it can be applied to a new facility. Space restrictions may be encountered in retrofitting (i.e., replacement of a scrubber with a fabric filter), which would would increase the capital cost but would not preclude the use of fabric filtration.

8.3 EMISSION LIMITS

When evaluating appropriate emission limits for a regulation, one must consider the control equipment that the emission limit will require. The capabilities of fabric filters, ESP's and scrubbers are discussed below.

8.3.1 Fabric Filters

Fabric filters, if operating properly, will deliver a relatively constant emission rate regardless of external conditions such as pressure drop or inlet grain loading. As a result, a properly designed fabric filter will meet any of the emission limits described in this chapter and will exceed the requirements of the SIP_1 and SIP_2 emission limits. As stated in Chapter 3, a properly operated fabric filter is capable of reducing emissions from phosphate rock dryers and calciners to less than 0.023 g/dry std. m^3 (0.01 gr/dscf). For a typical 181 Mg/h (200 tph) phosphate rock dryer with an exhaust flow rate of 44 m^3/s (93,500 acfm), this would result in an emission rate of 60 g/sec (8 lb/hr). For a typical phosphate rock calciner operating at 41 Mg/h (45 tph) and 21.4 m^3/s (45,200 acfm) of exhaust gas, the emission rate would be 29.3 g/sec (3.9 lb/hr), and for a typical 91 Mg/hr (100 tph) phosphate rock grinder with an exhaust gas flow rate of 5.2 m^3/s (11,000 acfm) the emission rate would be 7.2 g/sec (0.94 lb/hr).

If fabric filters were allowed to operate at the AEL level of control [0.07 g/dry standard m^3 (0.03 gr/dscf) for dryers and calciners and 0.035 g/dry standard m^3 (0.015 gr/dscf) for grinders], then the maximum allowable emission rates would be 180 g/sec (24 lb/hr), 88 g/sec (11.7 lb/hr), and 10.8 g/sec (1.41 lb/hr), respectively, for the typical phosphate rock dryers, calciners, and grinders characterized above.

8.3.2 Electrostatic Precipitators

As stated in Chapter 3, collecting surface (plate) area is one of the most important factors affecting the dust collection efficiency of electrostatic precipitators (ESP's). Since ESP's can theoretically be designed for any collection efficiency, economics rather than technical feasibility is the restraining factor when considering emission limits.

The plate area theoretically needed for the typical phosphate rock dryer [181 Mg/h and 44 m^3/s (200 tph and 93,500 acfm)] would range from 3,734 m^2 (40,150 ft^2) for the SIP_1 level to 5,233 m^2 (56,300 ft^2) for the AEL level. The typical phosphate rock calciner [41 Mg/h (45 tph) and 21.4 m^3/s (45,200 acfm)] would require 1,604 m^2 (17,251 ft^2) and 2,530 m^2 (27,205 ft^2) for the SIP_1 and AEL levels, respectively, and the typical phosphate rock grinder [91 Mg/h (100 tph) and 5.2 m^3/s (11,000 acfm)] would require from 252 m^2 (2,712 ft^2) to 699 m^2 (7,517 ft^2) for those levels of control.

For an ESP designed to achieve 0.023 g/dry standard M^3 (0.01 gr/dscf) and the AEL level of control, the emission rates will be the same as those presented in Section 8.3.1 for dryers, calciners, and grinders. The emission rates for the SIP_1 and SIP_2 levels are tabulated below:

Process	Production Rate Mg/hr (tph)		Exhaust Gas flow rate m^3/s (acfm)		Level of Control	Emission Rate g/sec (lb/hr)	
Dryer	181	(200)	44	(93,500)	SIP_1	454	(60)
					SIP_2	318	(42)
Calciner	41	(45)	21.4	(45,200)	SIP_1	325	(43)
					SIP_2	250	(33)
Grinder	91	(100)	5.2	(11,000)	SIP_1	378	(50)
					SIP_2	242	(32)

8.3.3 Venturi Scrubbers

The primary factor affecting the particulate collection efficiency of a venturi scrubber is the pressure differential (ΔP) under which it operates. Though the minimum ΔP required will differ for each of the nine process/control level combinations, the maximum ΔP required, as stated in Section 4.2.1, is 7.5 kPa (30 inches of water gage). The least stringent combination is the grinder operating under the SIP_1 regulation. It is estimated that a ΔP of only 1.5 kPa (6 inches water gage) would be required for this case.

The emission levels resulting from the various process/control level combinations will, of course, be the same as those presented in Sections 8.3.1 and 8.3.2.

8.4 FORMAT OF EMISSION LIMITS

As discussed in Chapter 7.0 there are several formats for specifying emission limits for emission sources in the phosphate rock industry. Generally, the most suitable format is a concentration limit, expressed as g/dry std. m^3 (gr/dscf) of a particulate matter in the outlet streams of control devices on all emission sources. In addition to the concentration limit, a maximum plume opacity limitation can also be specified for each emission source.

8.5 PROCESS MODIFICATIONS

The conversion of dry grinding operations to wet grinding offers considerable environmental, energy, and economic advantages when phosphate rock is produced for wet process phosphoric acid plants. This process change eliminates the drying operation with its energy requirements and emissions, and also eliminates emissions from grinding. Any increases in wastewater or solid waste are believed to be offset by the benefits of the process. As shown in Section 4.5, considerable cost savings can be realized by use of wet grinding (because of the reduction in energy consumption).

APPENDIX A. SUMMARY OF TEST DATA

A test program was undertaken by EPA to evaluate the best particulate control techniques available for controlling particulate emissions from phosphate rock dryers, calciners, grinders, and ground-rock handling systems. This appendix describes the facilities tested and summarizes the results of particulate tests and visible emission observations made by the EPA and operators.

Two dryers, one calciner, and five grinders were tested for particulate emissions using EPA Reference Method 5. In addition, visible emission observations were made at two dryers, one calciner, three grinders, and three ground-rock handling systems. These observations were made using EPA Reference Method 9. Results of the back-and front-half catches from the particulate emission measurements conducted are presented in Tables A-1 through A-3.

DESCRIPTION OF FACILITIES

A. The oil-fired (No. 6 fuel oil) rotary dryer was designed to reduce the moisture in phosphate rock from between 10 and 15 percent to less than 3 percent. Its pro-

Table A-1. PARTICULATE EMISSION TEST RESULTS ON PHOSPHATE ROCK DRYERS

(S.I. Units)

Facility Process Control Device	A[a] Dryer Venturi scrubber ΔP = 4.5 kPa L = 4.0 l/s	A[a] Dryer Venturi scrubber ΔP = 4.5 kPa L = 4.0 l/s	B[a] Dryer Wet collector 4700 m^2 ESP	B[b] Dryer Wet collector 4700 m^2 ESP
Date	3/19/75	9/4/74	3/20/75	6/10/74-8/14/74
Test time, min	108		108	N.R.
Production rate, Mg/h	219	327	353	384
Stack effluent				
Flow rate, m^3/s	54.939	51.45	62.479	58.704
Flow rate, dry std. m^3/s	34.869	30.68	52.836	54.444
Temperature, °K	340.	344.	316.	N.R.
Water vapor, % vol.	26.6	24.8	8.9	N.R.
Visible emissions at collector discharge, % max. opacity	0	0	7.7	N.R.
Particulate emissions				
Probe and filter catch				
g/dry std. m^3	0.0343	0.0503	0.0229	N.R.
g/actual m^3	0.0259	0.0297	0.0183	N.R.
kg/h	4.27	5.58	4.42	N.R.
g/Mg	19.5	19.0	12.5	N.R.
Total catch				
g/dry std m^3	0.117	0.0984	0.0297	0.0526
g/actual m^3	0.0732	0.0595	0.0252	0.0481
kg/h	14.59	10.93	5.82	10.34
g/Mg	66.51	33.51	16.50	27.01

[a] EPA Test Method 5.

[b] Operator performed tests using State of Florida Method.

N.R. - Not recorded.

Table A-1a. PARTICULATE EMISSION TEST RESULTS ON PHOSPHATE ROCK DRYERS

(English Units)

Facility Process Control Device	A[a,b] Dryer Venturi Scrubber ΔP = 18 in. WG L = 950 gpm	A[a] Dryer Venturi Scrubber ΔP = 18 in. WG L = 950 gpm	B[a] Dryer Wet Collector 50,600 ft^2 ESP	B[c] Dryer Wet Collector 50,600 ft^2 ESP
Date	3/19/75	9/4/74	3/20/75	6/10/74-8/14/74
Test time, min	108		108	N.R.
Production rate, tons/h	242	360	389	423
Stack Effluent				
Flow rate, acfm	116,397	109,000	132,371	124,373
Flow rate, dscfm	73,875	65,000	111,940	115,348
Temperature, °F	153	160	110	N.R.
Water vapor, % vol.	26.6	24.8	8.9	N.R.
Visible emissions at collector discharge, % opacity (maximum)	0	0	7.7	N.R.
Probe and filter catch				
gr/dscf	0.015	0.022	0.010	N.R.
gr/acf	0.009	0.013	0.008	N.R.
lb/h	9.42	12.3	9.74	N.R.
lb/ton	0.039	0.038	0.025	N.R.
Total catch				
gr/dscf	0.051	0.043	0.013	0.023
gr/acf	0.032	0.026	0.011	0.021
lb/h	32.16	24.1	12.84	22.8
lb/ton	0.133	0.067	0.033	0.054

[a] EPA Test Method 5.

[b] Company conducted test.

[c] Operator performed tests using State of Florida method.

N.R. - Not recorded.

Table A-2. PARTICULATE EMISSION TEST RESULTS ON PHOSPHATE ROCK CALCINERS[a]

(S.I. Units)

Facility Process Control Device	C Calciner Venturi Scrubber ΔP = 3 KPa L = 2.6 l/s	C[b] Calciner Venturi Scrubber ΔP = 3 KPa L = 2.6 l/s	C[b] Calciner Venturi Scrubber ΔP = 3 KPa L = 2.6 l/s	K Calciner Scrubber P = 5-7.5 kPa
Date	4/8-10/75	8/20/74	3/9/75	3/9/75 9/2/75 12/17/75
Test time, min	120	98	120	N.R.
Production rate, Mg/h	73	37.4	58.8	23.3
Stack effluent				
Flow rate, m^3/s	23.845	19.873	22.869	5.176
Flow rate, dry std. m^3/s	12.851	12.899	15.461	N.R.
Temperature, °K	337	326	328	N.R.
Water vapor, % vol.	24.2	10.9	6.37	N.R.
Visible emissions at collector discharge, % maximum opacity	0	N.R.	N.R.	N.R.
Particulate Emissions				
Probe and filter catch				
g/dry std. m^3	0.108	0.096	0.073	0.057
g/actual m^3	0.057	0.062	0.048	N.R.
kg/h	4.17	4.29	3.99	3.29
g/Mg	70.0	120.0	68.0	47.0
Total catch				
g/dry std. m^3	0.121			
g/actual m^3	0.064			
kg/h	5.57			
g/Mg	75.0			

[a] All tests conducted by EPA test Method 5.

[b] Conducted by company.

N.R. - Not recorded.

Table A-2a. PARTICULATE EMISSION TEST RESULTS ON PHOSPHATE ROCK CALCINERS[a]

(English Units)

Facility Process Control Device	C Calciner Venturi Scrubber ΔP = 12 in. WG L = 600 gpm	C Calciner Venturi Scrubber ΔP = 12 in. WG L = 600 gpm	C Calciner Venturi Scrubber ΔP = 12 in. WG L = 600 gpm	K Calciner Scrubber ΔP = 20-30 in. WG
Date	4/8-10/75	8/20/74	3/9/75	3/9/75 9/2/75 12/17/75
Test time, min	120	98	120	N.R.
Production rate, tons/h	80	41.2	64.8	25.7
Stack effluent				
Flow rate, acfm	50,520	42,103	48,451	10,967
Flow rate, dscfm	27,226	27,328	32,756	N.R.
Temperature, °F	146.7	127	132	N.R.
Water vapor, % vol.	24.2	10.90	6.37	N.R.
Visible emissions at collector discharge, % opacity (maximum)	0	N.R.	N.R.	N.R.
Probe and filter catch				
gr/dscf	0.047	0.042	0.032	0.025
gr/acf	0.025	0.027	0.021	N.R.
lb/h	9.20	9.46	8.80	7.26
lb/ton	0.14	0.24	0.136	0.094
Total catch				
gr/dscf	0.053			
gr/acf	0.028			
lb/h	12.29			
lb/ton	0.15			

[a] All tests are conducted by EPA Test Method 5.

[b] Conducted by company.

N.R. - Not recorded.

Table A-3. PARTICULATE EMISSION TEST RESULTS ON PHOSPHATE ROCK GRINDERS

(S.I. Units)

Facility Process Control Device	D[a] Grinder Fabric Filter	E[a] Grinder Fabric Filter	F[a] Grinder Fabric Filter Pulsed-air, filter velocity = 2 cm/s	F[b] Grinder Fabric Filter Pulsed-air, filter velocity = 2 cm/s	G[a] Grinder Fabric Filter Pulsed air, filter velocity = 2 cm/s	G[a] Grinder Fabric Filter Pulsed-air, filter velocity = 2 cm/s
Date	1/12/73	2/16/73	3/25/75	1/3/74-6/27/74	4/7/75	10/3/73
Test time, min	128	120	120	N.R.	200	120
Production rate, Mg/h	116	31.8	70.3	N.R.	73.6	47.2
Stack effluent						
Flow rate, m^3/s	7.03	1.563	3.912	N.R.	3.145	3.890
Flow rate, dry std. m^3/s	6.42	1.278	3.136	2.423	1.947	2.628
Temperature, °K	320	345	337	N.R.	386	350
Water vapor, % vol.	5.70	5.97	8.91	N.R.	0.0	0.28
Visible emissions at collector discharge, % maximum opacity	N.R.	N.R.	0	N.R.	0	
Particulate emissions						
Probe and filter catch						
g/dry std. m^3	0.0242	0.0149	0.0046	N.R.	0.0048	0.0112
g/actual m^3	0.0165	0.0121	0.0023	N.R.	0.0032	0.0076
kg/h	0.4981	0.0680	0.0467	N.R.	0.0363	0.109
g/Mg	4.40	2.10	0.650	N.R.	0.450	2.25
Total catch						
g/dry std. m^3	0.0295	0.0311	0.0069	0.0064	0.0071	
g/actual m^3	0.0217	0.0254	0.0046	N.R.	0.0043	
kg/h	0.649	0.142	0.0658	0.054	0.054	
g/Mg	0.60	4.45	0.950	N.R.	0.650	

[a] EPA Test Method 5.

[b] WP-50 Test Method conducted by company. Range of 15 tests over a 6-month period.

N.R. - Not recorded.

Table A-3a. PARTICULATE EMISSION TEST RESULTS ON PHOSPHATE ROCK GRINDERS

(English Units)

Facility Process Control Device	D[a] Grinder Fabric Filter	E[a] Grinder Fabric Filter	F[a] Grinder Fabric Filter Pulsed-air A/C = 4	F[b] Grinder Fabric Filter Pulsed-air A/C = 4	G[a] Grinder Fabric Filter Pulsed-air A/C = 5	G[a,c] Grinder Fabric Filter Pulsed-air A/C = 5
Date	1/12/73	2/16/73	3/25/75	1/3/74-6/27/74	4/7/75	10/3/73
Test time, min	128	120	120	N.R.	200	120
Production rate, tons/h	124	35.0	77.5	N.R.	81.1	52
Stack Effluent						
Flow rate, acfm	14,900	3,312	8,288	N.R.	6,663	8,241
Flow rate, dscfm	13,600	2,708	6,645	5,133	4,124	5,568
Temperature, °F	116	161	147	N.R.	235	171
Water vapor, % vol.	5.70	5.97	8.91	N.R.	0.0	0.28
Visible emissions at collector discharge, % maximum opacity	N.R.	N.R.	0	N.R.	0	
Particulate emissions						
Probe and filter catch						
gr/dscf	0.0098	0.0065	0.002	N.R.	0.0021	0.0049
gr/acf	0.0072	0.0053	0.001	N.R.	0.0014	0.0033
lb/h	1.098	0.150	0.103	N.R.	0.08	0.24
lb/ton	0.0088	0.0042	0.0013	N.R.	0.0009	0.0045
Total catch						
gr/dscf	0.0129	0.0136	0.003	0.0028	0.0031	
gr/acf	0.0095	0.0111	0.002	N.R.	0.0019	
lb/h	1.43	0.314	0.145	0.12	0.12	
lb/ton	0.0012	0.0089	0.0019	N.R.	0.0013	

[a] EPA Test Method 5.

[b] WP-50 Test Method conducted by company. Range of 15 tests over a 6-month period.

[c] Conducted by company.

N.R. - Not recorded.

duction rate varies from 200 to 400 Mg/h (220 to 440 tons/h), depending on the moisture content and the type of rock being processed. Florida land pebble was dried during each of the EPA tests and during the first test conducted by the operator. Flotation cell concentrates were being dried during the second operator test. Emissions from the dryer are cleaned by a Ducon venturi scrubber which has a pressure drop of 4.5 kPa (18 in. WG) and uses 60 liters/s (950 gal/min) of recirculated water. The EPA tests were conducted only while the process was operating normally. Both EPA and operator particulate measurements were performed using EPA Method 5. Visible emission measurements were made by EPA at the scrubber exhaust in accordance with EPA Method 9.

B. One oil-fired rotary dryer and one oil-fired fluid bed dryer were operated in parallel. Nominal production rates are 300 Mg/h (330 tons/h) for the rotary dryer and 150 Mg/h (165 tons/h) for the fluid bed dryer; however, actual production rate is dependent on the amount of moisture and type of rock fed to the dryers. Both dryers were operated normally at full capacity and processed 100 percent Florida land pebble for each of the EPA tests. Emissions from both dryers are partially cleaned by two parallel impingement scrubbers (one for each dryer). Emissions from the scrubbers are combined and ducted to a two-stage wet electrostatic precipitator (ESP), which has a total collecting area of 4700 m^2 (50,600 ft^2) and a gas velocity of 0.47 m/s (1.53 ft/s). The cleaned gas exits the ESP from two vertical stacks. The ESP was reportedly designed for approximately twice the volume of gas currently being processed. The EPA particulate measurements were performed using EPA Method 5. The operator conducted measurements using the State of Florida Department of Pollution Control Method. Visible emission observations were made at the ESP exhausts in accordance with EPA Method 9.

C. A fluid bed, oil-fired (No. 2 fuel oil) calciner was used to remove moisture and organics from phosphate rock. The calciner is designed to calcine 63.5 Mg/h (70 tons/h), but the operator has increased the calcining capacity to 73 Mg/h (80 tons/h) by drying a portion of the feed prior to calcination. Calciner emissions are cleaned by an ARCO venturi scrubber, which has a pressure drop of 3 kPa (12 in. WG) and uses about 38 liters/s (600 gal/min) recirculated water. Tests were conducted only while the process was operating normally. Both EPA and company particulate measurements were performed using EPA Method 5, and visible emissions were recorded using EPA Method 9.

D. A Kennedy Van Saun ball mill was used to grind phosphate rock. Production throughput is nominally rated at

112 Mg/h (124 tons/h), but is dependent on the degree of fineness to which the rock is ground. Emissions from the grinder are cleaned by a Mikro-Pulsaire baghouse. Tests were conducted only during normal process operation. Particulate measurements were performed using EPA Method 5. Visible emissions were not recorded.

E. A Raymond roller mill was used to grind dried phosphate rock. Production throughput is nominally rated 32 Mg/h (35 tons/h), but is dependent on the degree of fineness to which the rock is ground. During the first two tests, rock was ground to 65 percent through 200 mesh, and it was ground to 90 percent through 100 mesh (65 to 85 percent through 200 mesh), during the third test. Emissions from the grinder are cleaned by a baghouse. Tests were conducted only during periods when the process was operating normally. Particulate measurements were performed using EPA Method 5. Visible emission observations were not performed.

F. One roller mill and one bowl mill were operated in parallel. Production rates cannot be measured accurately, but experience shows that the roller mill normally operates at 25 Mg/h (27.5 tons/h) and the ball mill at 45 Mg/h (50 tons/h). To determine if mills are operating at full capacity, an amperage reading is made of the mill motors and fans. Mills were operated at full capacity during all EPA tests. Emissions from both grinders are combined and cleaned by a baghouse, which has a superficial filter velocity of 2 cm/s (4 ft/min). Tests were conducted only while the process was operating normally. The EPA particulate measurements were performed using EPA Method 5. Particulate measurements made by the operator were performed using Western Precipitation Method WP-50. The results are presented in Table A-3. Visible emission observations were made at the baghouse exhaust in accordance with EPA Method 9.

G. A Harding ball mill was used to grind calcined phosphate rock to 50 percent minus 200 mesh. Production throughput is nominally rated at 54 Mg/h (60 tons/h). Emissions from the grinder are cleaned by a Mikropul, pulse-air cleaned baghouse with a superficial filter velocity of 2.5 cm/s (5 ft/min). Tests were conducted only during periods when the process was operating normally. Both EPA and company particulate measurements were performed using EPA Method 5. Visible emission observations were made at the baghouse exhaust in accordance with EPA Method 9.

H. A pneumatic system was used to transfer ground phosphate rock from a storage silo at a phosphate rock grinder to a storage silo at a wet-process phosphoric acid plant. About 60 percent of the rock transferred was small enough to pass through a 200 mesh screen. The system was transferring about 54 Mg/h (60 tons/h) of ground rock, which is its normal operating rate. It has an exhaust gas flow rate of about 0.8 m^3/s (1700 dscfm). Emissions from the system pass first through a cyclone and then through a Mikro-Pulsaire baghouse, which has an filter velocity of 2 cm/s (4 ft/min). Visible emission measurements were made at the baghouse exhaust in accordance with EPA Method 9.

I. A fluid-bed, natural-gas-fired calciner was used to remove moisture and organics from phosphate rock. It was designed to calcine 41.7 Mg/h (46 tons/h), but operator has difficulty maintaining the design production rate because of lack of surge capacity between calciner and grinder. Calciner emissions are cleaned by an Entoleter Centrifield scrubber, which operates in a range of 5 to 6 kPa (20 to in. WG) pressure drop. Particulate measurements were conducted by the operator, using EPA Method 5, while the calciner was operating normally. Visible emissions were recorded by EPA, using EPA Method 9, but these measurements were not recorded simultaneously with the Method 5 tests.

APPENDIX B - EMISSION REGULATIONS

ALTERNATIVE EMISSION LEVEL (AEL)

On March 18, 1976, Federal New Source Performance Standards were recommended for dryers, calciners, grinders, and ground-rock transfer systems. However, as of the publication of this document, standards have not yet been proposed.

The tentative recommendations were to limit particulate emissions from dryers and calciners to no more than 0.071 g/dry std. m^3 (0.031 gr/dscf) and visible emissions to less than 10 percent opacity. Particulate emissions from rock grinders were to be limited to no more than 0.030 g/dry std. m^3 (0.013 gr/dscf: and visible emission to less than 5 percent opacity. Recommended NSPS for particulate emissions from ground-rock transfer systems stipulated no visible emissions. These recommended emission levels were considered as the alternative emission levels (AEL) used in this document.

STATE EMISSION LIMITATIONS

Figure B-1 illustrates the maximum allowable particulate emission rate in pounds per hour as a function of process throughput in tons per hour for sources covered by

State Implementation Plans (SIP). Florida's regulation (Appendix C) is the most stringent; however, if Tennessee or Wyoming sources are subject to state NSPS, then the allowable emissions for soucres in these states are the same as for Florida sources. Utah requires an emission reduction of at least 85 percent.

SIP emission levels are illustrated in terms of g/dry std. m^3 (gr/dscf) in Figures B-2, B-3, and B-4 for dryers, calciners, and grinders. These figures compare uncontrolled, AEL, and SIP emission levels for the range of flow rates given.

Because a source meets mass emission limits does not guarantee its compliance with opacity regulations. This is particularly true for processes with a small throughput capacity. The design of control equipment in this document, especially scrubbers and electrostatic precipitators (ESP's), is based only on meeting the mass emission limits, even though in some cases this control is not sufficient to meet opacity regulations. The opacity of particulate emissions is difficult to predict since this property is dependent upon stack diameter, velocity, particle size and color, and other variables.

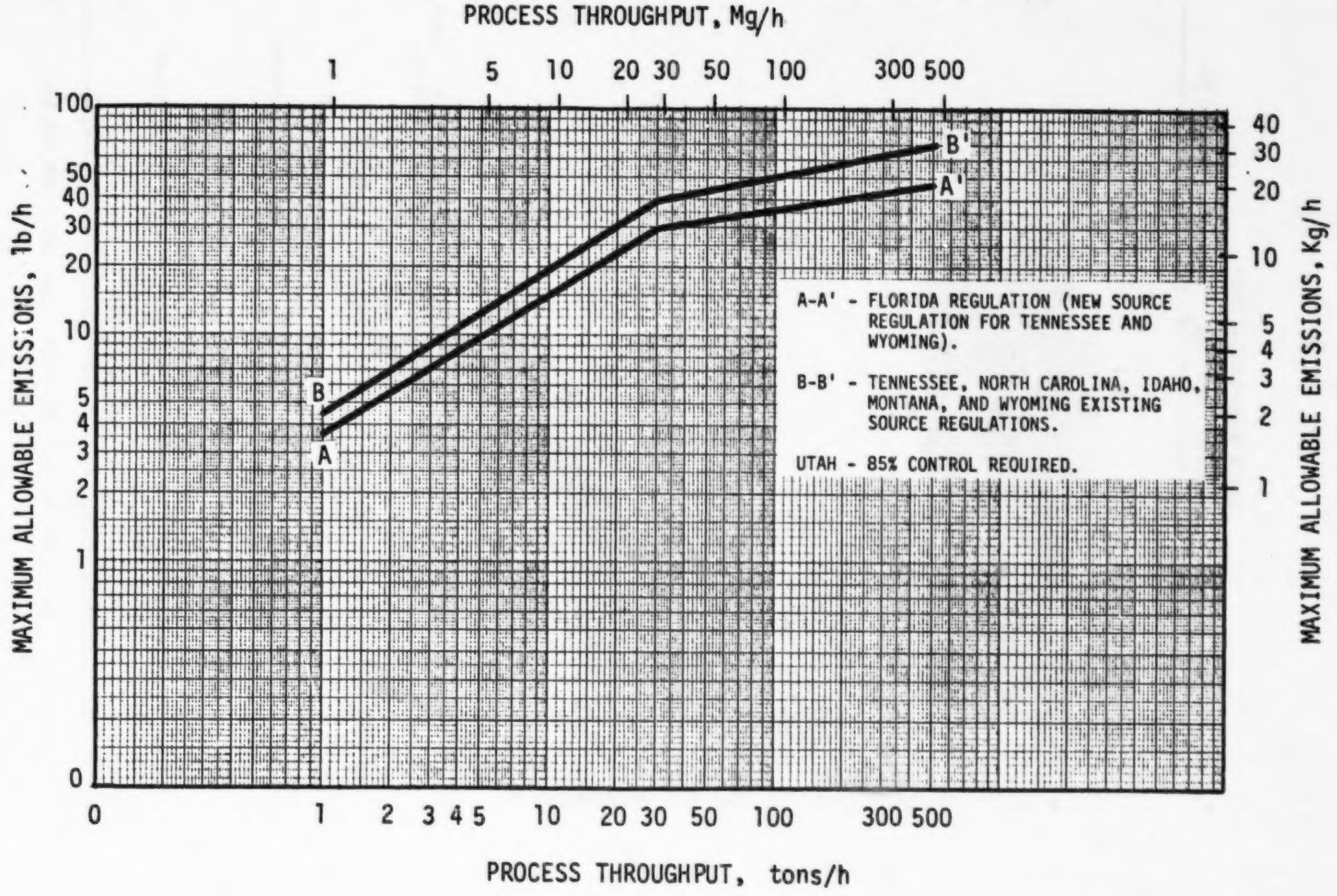
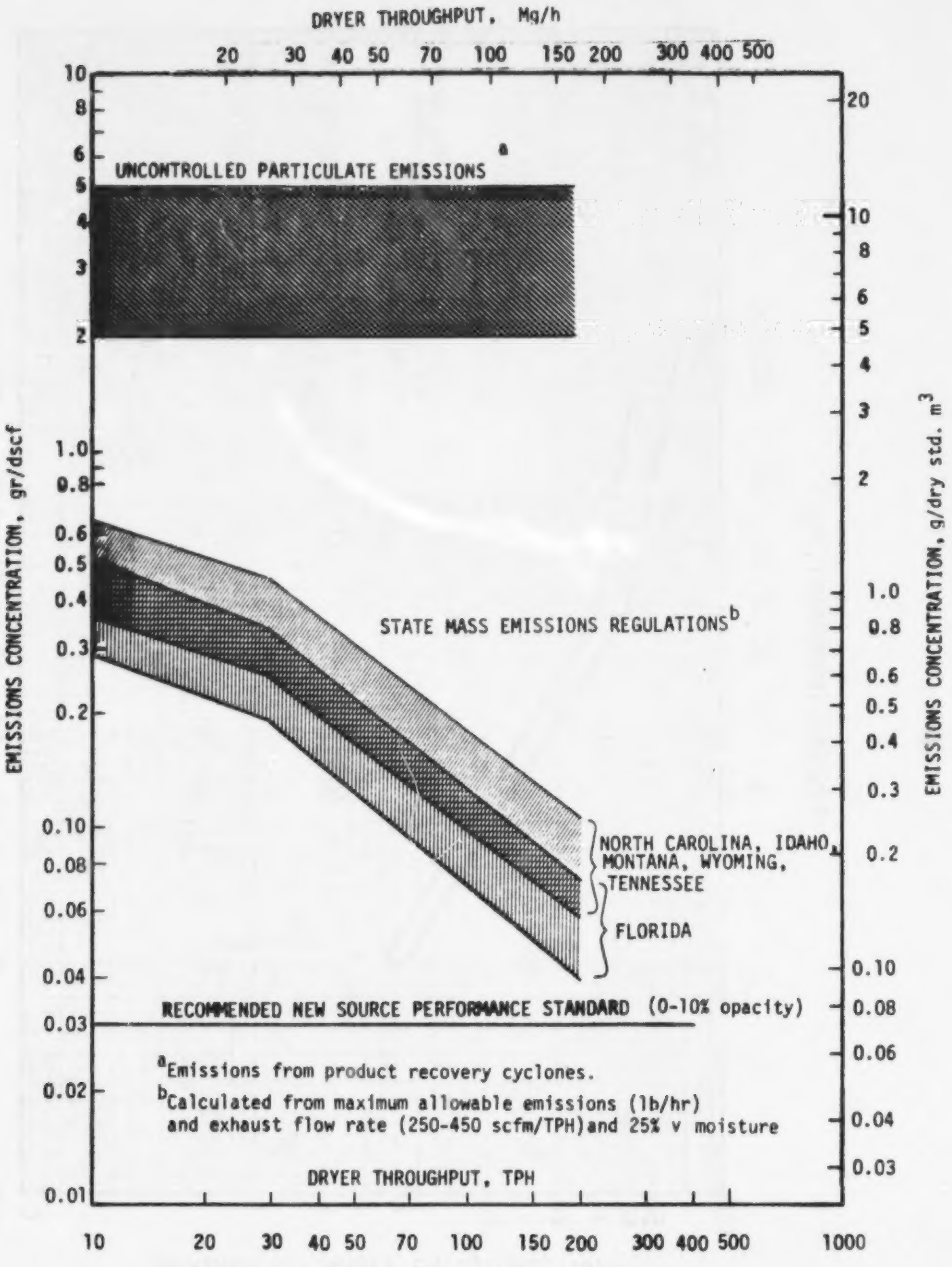


Figure B-1. State mass emission limitations for new and existing sources.[2]



[a] Emissions from product recovery cyclones.

[b] Calculated from maximum allowable emissions (lb/hr) and exhaust flow rate (250-450 scfm/TPH) and 25% v moisture

Figure B-2. Comparison of uncontrolled emissions with state and Federal limitations for phosphate rock dryers.

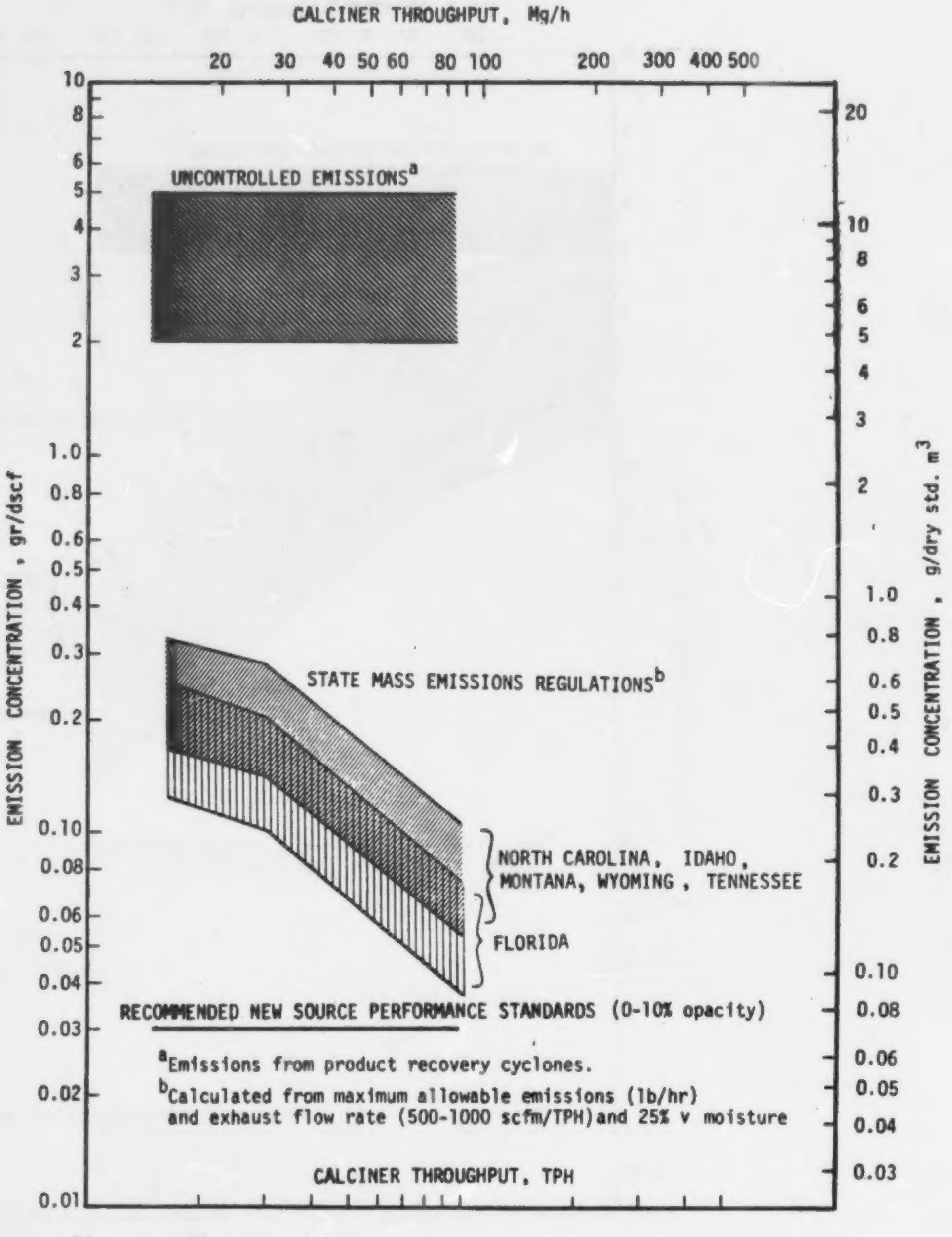


Figure B-3. Comparison of uncontrolled emissions with state and Federal limitations for phosphate rock calciners.

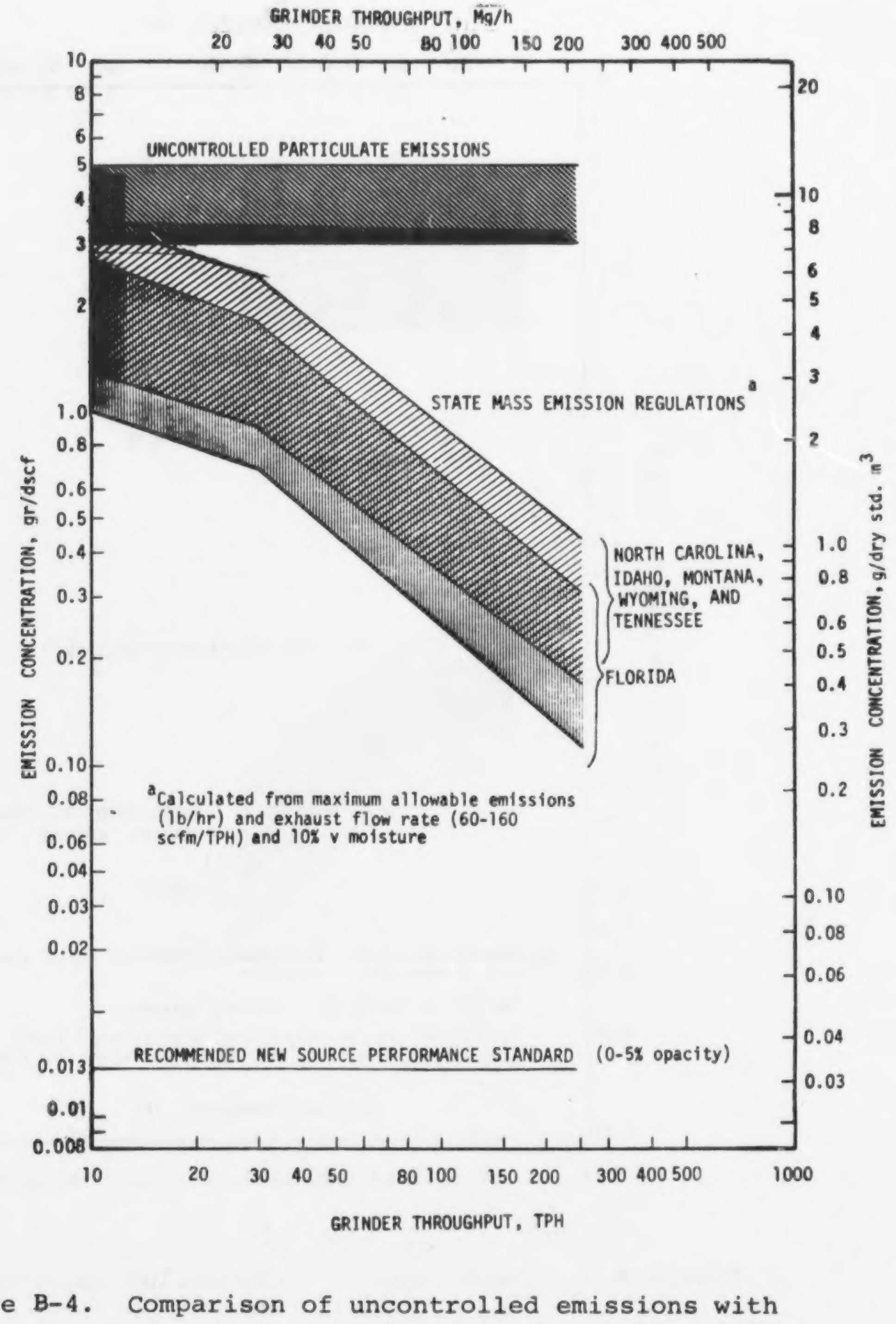


Figure B-4. Comparison of uncontrolled emissions with state and Federal limitations for phosphate rock grinders.

APPENDIX C

FLORIDA AIR POLLUTION RULES OF THE DEPARTMENT OF POLLUTION CONTROL

APPENDIX C

FLORIDA AIR POLLUTION RULES
OF THE DEPARTMENT OF POLLUTION CONTROL

(Florida Administrative Code, Chapter 17-2, Air Pollution; Amended February 11, 1972; September 24, 1973; April 9, 1974; April 25, 1974; December 28, 1974; June 30, 1975)

17-2.01 *Declaration and Intent*

The State of Florida Department of Pollution Control promulgates this chapter to eliminate, prevent, and control air pollution. This chapter shall apply to all sources of air pollution except open burning or the use of outdoor heating devices allowed by chapter 17-5, Florida Administrative Code, unless otherwise provided in this chapter.

To protect and enhance the air quality of Florida, this chapter furthers the Department's nondegradation policy and establishes ambient air quality standards and emission standards. The policy inherent in the standards shall be to protect the air quality existing at the time the air quality standards were adopted or to upgrade or enhance the quality of the air of the State. In any event, where a new or increased source of air pollution poses a possibility of degrading existing high air quality or ambient air quality established by this chapter, such source or proposed source shall not be issued a Department permit until the Department has reasonable assurance that such source construction or development will not violate this chapter.

This chapter is adopted to achieve and maintain such levels of air quality as will protect human health and safety, prevent injury to plant and animal life and property, foster the comfort and convenience of the people, promote the economic and social development of this State and facilitate the enjoyment of the natural attractions of this State.

General Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061 FS. History – New 1-11-72.

17-2.02 *Definitions*

The following words and phrases when used in this chapter shall, unless context clearly indicates otherwise, have the following meanings:

(1) "Air pollutant" – Any matter found in the atmosphere other than oxygen, nitrogen, water vapor, carbon dioxide and the inert gases in natural concentrations.

(2) "Air pollutant source" or "source" – Any source at, from, or by reasons of which there is emitted into the atmosphere any air pollutant(s).

(3) "Process weight" – The total weight of all materials introduced into any process. Solid fuels and recycled materials are included in the determination of process weights; but uncombined water, liquid and gaseous fuels, combustion air or excess air are not included.

(4) "Standard conditions" – A gas temperature of 70 degrees fahrenheit and a gas pressure of 14.7 psia.

(5) "Existing source" – A source which is in existence, (except for reactivation of older plants) operating or under construction or has received a permit to construct prior to the effective date of this chapter.

(6) "New Source" – Any source other than an existing source. New source includes reactivating existing or older plants which have been shutdown for a period of more than one year.

(7) "Particulate matter" – Means any material, other than uncombined water, which exists in a finely divided form as a liquid or solid, as measured by the sampling methods approved by the Board.

(8) "Sulfuric Acid Plant" – Means any installation producing sulfuric acid by the contact process by burning elemental sulfur, alkylation acid, hydrogen sulfides, organic sulfides and mercaptans, or acid sludge.

(9) "Acid mist" – Means any size liquid drops of any acid including but not limited to sulfuric acid and sulfur trioxide, hydrochloric acid and nitric acid as measured by test methods approved by the Board.

(10) "Visible emission" – Means an emission greater than 5 percent opacity or 1/4 Ringelmann measured by standard methods.

(11) "Fugitive particulate" Particulate matter which escapes and becomes airborne from unenclosed operations or which is emitted into the atmosphere without passing or being conducted through a flue pipe, stack or other structure designed for the purpose of emitting air pollutants into the atmosphere.

(12) "Air Pollution Episode" – An occurrence of elevated levels of pollutants in the atmosphere which require hasty and unusual abatement action.

(13) "Odor" – Means a sensation resulting from stimulation of the human olfactory organ.

(14) "Objectionable Odor" – Any odor present in the outdoor atmosphere which by itself or in combination with other odors, is or may be harmful or injurious to human health or welfare, which unreasonably interferes with the comfortable use and enjoyment of life or property, or which creates a nuisance.

(15) "Fossil fuel steam generators" Furnaces and boilers which produce steam by combustion of oil, coal or gas of fossil origin.

(16) "Plant section" – A part of a plant consisting of one or more unit operations including auxiliary equipment which provides the complete processing of input (raw) materials to produce a marketable product, including but not limited to, granular triple super phosphate, phosphoric acid, run-of-pile triple super phosphate and di-ammonium phosphate, or one or more unit operations including auxiliary equipment or structures which are used for the functions of, including but not limited to, storage, shipping, loading, unloading, or bagging.

(17) "Department" – Means the State of Florida Department of Pollution Control.

(18) "Director" – Means the Executive Director of the Department.

(19) "Volatile organic compounds" or "Organic Solvents" – Are any compounds containing carbon and hydrogen or carbon and hydrogen in combination with any other element which has a vapor pressure of 1.5 pounds per square inch absolute (77.6 mm. Hg) or greater under actual storage conditions.

(20) "Portland cement plant" – Means any facility manufacturing Portland Cement by either the wet or dry process.

(21) "Nitric acid plant" – Means any facility producing weak nitric acid by either the pressure or atmospheric pressure process.

(22) "Kraft Pulp Mill" – Means an industrial operation which processes wood to produce cellulose or cellulose materials by means of chemically cooking the wood with a liquor consisting of an alkaline sulfide solution containing sodium hydroxide and sodium sulfide, also known as the sulfate process.

(23) "Sulphur Recovery Plant" – Any plant that recovers sulphur from crude (unrefined) petroleum materials.

(24) "Ringelmann Chart" – Means the chart published and described in the U.S. Bureau of Mines Information Circulars No. 8333 and No. 7718.

(25) "Stagnant atmospheric condition" – Denotes when the atmospheric and meteorological conditions will reduce the necessary diffusion and dispersement of air pollutants in the atmosphere.

(26) "Opacity" – Means a state which renders material partially or wholly impervious to rays of light causing obstruction of observer's view.

(27) "Carbonaceous Fuel" – Means solid materials composed primarily of vegetative matter such as tree bark, wood waste, bagasse, and/or the combustible fraction of municipal wastes.

(28) "Fossil Fuel" – Means natural gas, petroleum, coal or any form of solid, liquid, or gaseous fuel derived from such material.

(29) "Carbonaceous Fuel Burning Equipment" – A fire box, furnace or combustion device which burns carbonaceous fuel or a combination of carbonaceous and fossil fuel for the primary purpose of producing thermal energy which is used indirectly to produce steam or to heat other liquids or gases, including, but not limited to, bagasse burners, bark burners, and waste wood burners, but not intended to include teepee or conical wood burners or incinerators.

(30) "Latest Reasonably Available Control Technology" means air pollution control equipment, facilities, or devices or processes (including fuels and raw materials used) which cause or allow the least emission of pollutant(s) and which have been determined to be reasonably available in accordance with Section 17-2.03 (1), Florida Administrative Code.

General Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.087 F.S.

17-2.03 *General Restrictions*

(1) *Latest Reasonably Available Control Technology.*

(A) Determination – the Department shall determine Latest Reasonably Available Control Technology.

(1) In making the determination the Department shall give due consideration to:

a. Environmental Protection Agency determinations of Reasonably Available Control Technology pursuant to 40 C.F.R. Section 51.1 (o) and 40 C.F.R., Part 51, Appendix B; and Environmental Protection Agency determinations of Standards of Performance for New Stationary Sources, pursuant to 40 C.F.R., Part 60.

b. All scientific, engineering, and technical material, reports, publications, journals, and other competent relevant information made available to or known by the Department.

c. Recommendations of any ad hoc technical advisory committee appointed pursuant to paragraph 3 of this Subsection (17-2.03 (1) (a)).

d. The social and economic impact of the application of such technology, including consideration of any useful life of presently installed control equipment and the amortization of the value of such equipment balanced with the cost and advantages of the new technology; public interest served by such equipment; and other appropriate factors, such as materials, manufacturing processes, all environmental impacts, control and treatment technology available, ability to construct, install, and operate the facility, energy requirements, and cost.

(2) The Department shall specify and publish its determination of Latest Reasonably Available Control Technology by source or category of sources.

(3) To assist the Department in making the determination of Latest Reasonably Available Control Technology, the Executive Director may appoint an ad hoc technical advisory committee of persons with expertise and knowledge in the particular matter under consideration. The committee shall be representative of scientific, affected industry, citizen, and conservation interests. If an affected party so requests the committee shall be appointed.

(4) Any citizen or affected party may, in accordance with the Florida Administrative Procedures Act, Chapter 120, Florida Statutes, request a determination of Latest Reasonably Available Control Technology for a source or category of sources.

(5) The determination of Latest Reasonably Available Control Technology shall be made by the Board only after notice and public hearing is requested by an affected party.

(6) Determinations of Latest Reasonably Available Control Technology shall be periodically reviewed by the Department, and shall be subject to revision in accordance with this Section 17-2.03 (1), Florida Administrative

Code, subsequent to such review if the Board determines, on the basis of competent substantial evidence, that different equipment, devices or processes will result in reduction of emissions.

(B) Application

(1) If the application of the Latest Reasonably Available Control Technology to an air pollutant source will result in lower or improved air pollutant emissions, then the Department shall require that the Latest Reasonably Available Control Technology be applied.

(2) Exceptions.

The Latest Reasonably Available Control Technology shall not be required:

a. If there is an emission limiting standard for the source and it is being complied with; and

b. If the source complies with all requirements of any duly promulgated air quality maintenance or improvement plan adopted by the Department; and

c. If the source complies with the Department Rule Section 17-2.03 (4) (b), Florida Administrative Code; and

d. If the Department does not find that public interest factors other than those in a., b., and c. above require the use of Latest Reasonably Available Control Technology. In making such a finding the Department shall;

1. Give due consideration to all the following:

(a) The necessity of imposing the level of emission limitation which would be achieved by the application of such technology in order to attain and maintain Ambient Air Quality Standards specified in Section 17-2.05, and prevent degradation of air quality in accordance with these rules; and

(b) The social and economic impact of the application of such technology, including consideration of any useful life of presently installed, permitted control equipment and the amortization of the value of such equipment balanced with the cost and advantages of the new technology; and

(c) The energy consumption or conservation associated with such technology; and

(d) Alternative means of providing attainment and maintenance of the Ambient Air Quality Standards specified in Section 17-2.05, and the prevention of degradation of air quality in accordance with these rules; and

(e) Secondary pollution problems created by the application of any particular technology.

2. Provide the owner or operator of the source adequate notice and an opportunity for public hearing.

3. Set forth its specific findings on applicable issues and ultimate determination and the rationale therefor, if requested by a party prior to the hearing.

(3) For those sources for which there is no emission limiting standard, the application of Latest Reasonably Available Control Technology shall be required unless:

(I) The owner of the source affirmatively shows that

(1) The source complies with all requirements of any duly promulgated air quality maintenance or improvement plan adopted by the Department; and

(2) The source complies with the Department Rule Section 17-2.03 (4) (b), Florida Administrative Code; and

(II) The owner of the source affirmatively shows and the Department finds after considering all the matters set forth in (B) (2) d. 1. that the application of LRACT is not necessary to the public interest.

(2) *Existing Source Compliance* – Except where compliance dates are specified, existing sources shall comply with this chapter as expeditiously as possible but in no case later than July 1, 1975.

(3) *Operation Rates* – No plant or source shall operate at capacities which exceed the limits of operation of a control device or exceed the capability of the plant or control device to maintain the air emission within the standard limitation imposed by this chapter, or by permit conditions.

(4) (a) *Air Quality Standards Violated* – No person shall build, erect, construct, or implant any new source or operate, modify or rebuild an existing source or by any other means release or take action which would result in release of air pollutants into the atmosphere of any region, which will, as determined by the Board, result in, including concentrations of existing air pollutants, ambient air concentrations greater than ambient air quality standards.

(b) Significant Degradation

(i) "In those counties of the state which have a baseline air quality better than that defined by the Ambient Air Quality Standards, Section 17-2.05, no person shall emit into the atmosphere any air pollutant which significantly degrades that quality and in such counties no person shall construct a new source or expand an existing source, groups of sources, or a complex source which by itself, or in association with mobile sources, significantly degrades the baseline air quality."

(ii) Whether a new source or proposed expansion of an existing source will significantly degrade the baseline air quality shall be determined by the Board only after;

a) Notice and hearing,

b) Considering all relevant matters, and

c) The source owner has affirmatively demonstrated that the degradation is not contrary to the public interest.

(iii) Increases of air pollution levels or Baseline Air Quality may be determined by use of scientifically valid predictive air quality dispersion models.

(iv) No increase in pollutant concentrations above the baseline air quality will be allowed unless the latest reasonably available control technology is utilized to control emissions from the source.

(v) The phrase "Baseline Air Quality" means the maximum concentrations of pollutants in the ambient air representative of one of the following calendar years measured or estimated in the area in which the proposed new source or expanded source would have a significant effect:

a) Calendar year 1973 for all sources except fossil fuel steam generators,

b) Calendar year 1972 for all fossil fuel steam generators, except such steam generators which were burning natural gas during this period of time, or

c) For those fossil fuel steam generators which were burning natural gas during 1972, the baseline will be calculated as if said generators were burning the BTU equivalent of 2.5% sulfur content oil.

In the absence of air quality data, any approved air quality dispersion model may be used to predict the Baseline Air Quality.

(vi) This Subsection 17-2.03 (4) (b), F.A.C., shall be effective for one year or until such time that a superceding rule is duly adopted; provided however, that in the event a superceding rule is not adopted within a one year period this subsection shall cease to be operative, and the Subsection 17-2.03 (4) (b), which was adopted by the Florida Pollution Control Board on January 11, 1972 and which became effective on January 18, 1972, shall become effective and operative at the end of the one year period.

(5) *Concealment* – No person shall build, erect, install or use any article, machine, equipment or other contrivance, the use of which will conceal an emission which would otherwise constitute a violation of any of the provisions of this chapter.

(6) *Circumvention* – No person shall circumvent any air pollution control device, or allow the emission of air pollutants without the applicable air pollution control device operating properly.

(7) *Maintenance* – All air pollution control devices and systems shall be properly and consistently maintained in order to maintain emissions in compliance with Department Rules.

General Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061 FS. History – New 1-11-72.

17-2.04 *Prohibitive Acts*

(1) Visible Emissions – No person shall cause, let, permit, suffer or allow to be discharged into the atmosphere any air pollutants from:

(a) Existing Sources, until July 1, 1975, the density of which is equal to or greater than that designated as Number 2 on the Ringelmann Chart or the opacity of which is equal to or greater than 40 percent.

(b) New Sources, and after July 1, 1975, existing sources, the density of which is equal to or greater than that designated as Number 1 on the Ringelmann Chart or the opacity of which is equal to or greater than 20 percent.

(c) This subsection 17-2.04(1) does not apply to emissions emitted in accordance with specified emission limiting standards or in accordance with the process weight table (Table I) provided in this chapter.

(d) If the presence of uncombined water is the only reason for failure to meet visible emission standards given in this section such failure shall not be a violation of this rule.

(2) Particulate Matter – No person shall cause, let, permit, suffer, or allow the emission of particulate matter from any air pollutant source in total quantities in excess of the amount shown in Table I, except as otherwise provided for in this chapter for specific emission limiting standards of particulate matter from specified sources.

PROCESS WEIGHT TABLE

TABLE I

Process Weight Rate (pounds per hour)	Emission rate (pounds per hour)
50	0.03
100	0.55
500	1.53
1,000	2.25
5,000	6.34
10,000	9.73
20,000	14.99
60,000	26.90
80,000	31.19
120,000	33.28
160,000	34.85
200,000	36.11
400,000	40.35
1,000,000	46.72

Interpolation of the data in Table I for the process weight rates up to 60,000 pounds per hour shall be accomplished by the use of the equation: $E=3.59P^{0.62}$, P less than or equal to 30 tons per hour and interpolation and extrapolation of the data for process weight rates in excess of 60,000 pounds per day shall be accomplished by use of the equation: $E= 17.31P^{0.16}$, P is greater than 30 tons per hour. Where: E = Emissions in pounds per hour. P = Process weight rate in tons per hour. Application of mass emission limitations on the basis of all similar units at a plant is recommended in order to avoid unequal application of this type of limitation to plants with the same total emission potential but different size units. Upon establishing the total mass limitation, individual source emissions will be determined by prorating the mass emission total on the basis of the percentage weight input to each source process.

(3) Fugitive Particulate – No person shall cause, let, permit, suffer or allow the emissions of particulate matter, from any source whatsoever, including but not limited to vehicular movement, transportation of materials, construction, alteration, demolition or wrecking, or industrially related activities such as loading, unloading, storing or handling, without taking reasonable precautions to prevent such emission, except particulate matter emitted in accordance with the weight process table (Table I), the visible emissions standards or specific source limiting standards specified in this chapter.

(4) Objectionable Odor Prohibited – No person shall cause, suffer, allow or permit the discharge of air pollutants which cause or contribute to an objectionable odor.

(5) Volatile organic compounds emissions or organic solvents emissions.

(a) No person shall store, pump, handle, process, load, unload or use in any process or installation volatile organic compounds or organic solvents without applying known and existing vapor emission control devices or systems deemed necessary and ordered by the Department.

(b) All persons shall use reasonable care to avoid discharging, leaking, spilling, seeping, pouring, or dumping volatile organic compounds or organic solvents.

(6) Stationary sources – No person shall cause, let, permit, suffer, or allow to be discharged into the atmo-

sphere emission from the following listed sources greater than any emission limiting standard given.

(a) Incinerators

1. The emission limiting standards for new incinerators with a charging rate of fifty or more tons per day are:

a. Particulate matter -- 0.08 grains per standard cubic foot dry gas corrected to 50 percent excess air.

b. Odor -- there shall be no objectionable odor.

2. The emission limiting standards for new incinerators with a charging rate of less than fifty tons per day are:

a. Visible emissions - no visible emissions except, visible emissions are allowable for up to three minutes in any hour at densities up to but not more than, a density of Ringelmann Number 1. (Opacity of 20 percent)

b. Odor -- there shall be no objectionable odor.

3. As soon as possible, but not later than July 1, 1975, existing incinerators shall comply with the standards for new incinerators except that the particulate matter emission limiting standard for existing incinerators with a charging rate of fifty or more tons per day shall be 0.1 grains per standard cubic foot of dry gas corrected to 50 percent excess air.

(b) Sulfuric Acid Plants - the emission limiting standards for sulfuric acid plants are:

1. Existing Plants

a. Sulfur dioxide (SO_2) -- ten pounds of SO_2 per ton of 100 percent H_2SO_4 produced, as expeditiously as possible but not later than July 1, 1975; in the Florida portion of the Jacksonville, Florida -- Brunswick, Georgia, Interstate Air Quality Control Region as defined in 40 C.F.R. Section 81.91, twenty-nine pounds of SO_2 per ton of 100 percent H_2SO_4 produced as expeditiously as possible but not later than July 1, 1975.

b. A plume with visibility of 5 percent opacity (equivalent to 1/4 Ringelmann Number), except for 30 minutes during plant startup periods with opacity allowed up to 40 percent (equivalent to Ringelmann Number 2)

2. New Plants

a. Sulfur dioxide -- four pounds of SO_2 per ton of 100 percent H_2SO_4 produced.

b. Acid Mist -- 0.15 pounds per ton of 100 percent acid produced.

c. No visible emission except for 30 minute period during startup, but no greater than the opacity of 40 percent (equivalent to Ringelmann Number 2)

(c) Phosphate Processing -- the emission limiting standards for phosphate processing are:

1. Fluorides (water soluble or gaseous-atomic weight 19) the following quantities expressed as pounds of fluoride per ton of phosphatic materials input to the system, expressed as tons of P_2O_5 for:

a. New plants or plant sections:

a 1. Wet process phosphoric acid production, and auxiliary equipment -- 0.02 pounds of F per ton of P_2O_5.

a 2. Run of pile triple super phosphate mixing belt and den and auxiliary equipment -- 0.05 pounds of F per ton of P_2O_5.

a 3. Run of pile triple super phosphate curing or storage process and auxiliary equipment -- 0.12 pounds of F per ton of P_2O_5.

a 4. Granular triple super phosphate production and auxiliary equipment.

i. Granular triple super phosphate made by granulating run-of-pile triple super phosphate 0.06 pounds of F per ton of P_2O_5.

ii. Granular triple super phosphate made from phosphoric acid and phosphate rock slurry -- 0.15 pounds of F per ton of P_2O_5.

a 5. Granular triple super phosphate storage and auxiliary equipment -- 0.05 pounds of F per ton of P_2O_5.

a 6. Di ammonium phosphate production and auxiliary equipment -- 0.06 pounds of F per ton of P_2O_5.

a 7. Calcining or other thermal phosphate rock processing and auxiliary equipment excepting phosphate rock drying and defluorinating -- 0.05 pounds of F per ton of P_2O_5.

a 8. Defluorinating phosphate rock by thermal processing and auxiliary equipment -- 0.37 pounds of F per ton of P_2O_5.

a 9. All plants, plant sections or unit operations and auxiliary equipment not listed in a.1 to a.8 will comply with best technology pursuant to Section 2.03(1) of this rule.

b. Existing plants or plant sections. Emissions shall comply with above section, 17-2.04(6)(c) 1.a., for existing plants as expeditiously as possible but not later than July 1, 1975 or

b 1. Where a plant complex exists with an operating wet process phosphoric acid section (including any items 17-2.04(6) 1., a., a.1. through a.6. above) and other plant sections processing or handling phosphoric acid or products or phosphoric acid processing, the total emission of the entire complex may not exceed 0.4 pounds of F per ton of P_2O_5 input to the wet process phosphoric acid section.

b 2. For the individual plant sections included in 17-2.04(6)(c), 1., a., a.1. through a.6 above but not included as a part as defined in 17-2.04(6)(c)1., b., b.1 above, if it can be shown by comprehensive engineering study and report to the Department that the existing plant sections are not suitable for the application of existing technology, which may include major rebuilding or repairs and scrubber installations, the emission limiting standard to apply will be the lowest obtained by any similar plant section existing and operating.

(d) Kraft (sulfate liquor) Pulp Mills

1. Black liquor recovery furnace. The emission limiting standards are:

a. Particulate matter -- existing sources as expeditiously as possible, but not later than July 1, 1975, no greater than three pounds particulate per each 3,000 pounds black liquor solids fed. For new sources the same emission limiting standards apply.

b. Total Reduced Sulfur -- existing plants as expeditiously as possible, but not later than July 1, 1975 -- 17.5 ppm expressed as H_2S on a dry gas basis, or one-half (0.5) pounds per 3,000 pounds of black liquor solids fed, whichever is more restrictive. For new plants no greater than 1 ppm expressed as H_2S on the dry basis, or 0.03 pounds per 3,000 pounds of black liquor solids fed, whichever is the more restrictive.

(e) Fossil Fuel Steam Generators - The emission limiting standards for Fossil Fuel Steam Generators are:

1. New Sources – plants with more than 250 million BTU per hour heat input.

a. Particulate matter – 0.1 pounds per million BTU heat input, maximum 2 hour average.

b. Visible emissions – the density of which is equal to or greater than Number 1 of the Ringelmann Chart (20 percent opacity) except that a shade as dark as Number 2 of the Ringelmann Chart (40 percent opacity) shall be permissible for not more than 2 minutes in any hour.

c. Sulfur Dioxide – 0.8 pounds per million BTU heat input, maximum 2 hour average, when liquid fuel is burned.

d. Sulfur dioxide – 1.2 pounds per million BTU heat input, maximum 2 hour average, when solid fuel is burned.

e. Nitrogen oxides – 0.20 pounds per million BTU heat input maximum 2 hour average, expressed as NO_2 when gaseous fuel is burned.

f. Nitrogen oxides – 0.30 pounds per million BTU heat input, maximum 2 hour average, expressed as NO_2 when liquid fuel is burned.

g. Nitrogen oxides – 0.70 pounds per million BTU heat input, maximum 2 hour average, expressed as NO_2 when solid fuel is burned.

2. Existing Sources – plants with more than 250 million BTU per hour heat input.

a. Particulate – no greater than the standard for new sources.

b. Visible emissions – no greater than the standard for new sources.

c. Sulfur dioxide emissions – When liquid fuel is burned emissions shall be no greater than 2.75 pounds per million BTU heat input for sources in all areas of the State except as follows:

(i) 2.5 pounds per million BTU heat input for sources north of Hecksher Drive within Duval County and 1.65 pounds per million BTU heat input for all other sources in Duval County.

(ii) 1.1 pounds per million BTU heat input for all sources in Hillsborough County including Tampa Electric Company's Gannon Station Units 1 through 4 and Hooker's Point Generation Station.

d. Sulfur dioxide emissions – When solid fuel is burned emissions shall be no greater than 6.17 pounds per million BTU heat input for sources in all areas of the State, except for the following sources in Hillsborough County the emissions shall be no greater than:

(i) 2.4 pounds per million BTU heat input for Units 5 and 6 at Tampa Electric Company's Francis J. Gannon Generating Station and;

(ii) 6.5 pounds per million BTU heat input at Tampa Electric Company's Big Bend Generating Station.

e. This rule shall be re-evaluated and reconsidered by the Board at a public hearing prior to July 1, 1977. As part of the re-evaluation and reconsideration required by this rule, the Department shall consider and give due weight to all competent substantial evidence including any findings and conclusions of any studies directed or supervised by the Board. Unless the Board finds that the emission limitations set forth in Section 17-2.04(6)(e) 2.c & d adequately protect public health and welfare, existing fossil fuel steam generators shall be subjected to compliance schedules which must be submitted to the Department on or before August 1, 1977 and which propose increments of progress dates that will as expeditiously as possible bring them into compliance with the following emission limiting standards:

(i) Sulfur dioxide – 1.1 pounds per million BTU heat input when liquid fuel is burned.

(ii) Sulfur dioxide – 1.5 pounds per million BTU heat input when solid fuel is burned.

If the Board finds that the emission limitations set forth in 17-2.04(6)(e) 2.c & d adequately protect public health and welfare this rule shall be continued or amended to reflect such findings and conclusions.

f. Owners of fossil fuel steam generators shall monitor their emissions and the effects of the emissions on ambient concentrations of sulfur dioxide, in a manner, frequency, and locations approved, and deemed reasonably necessary and ordered by the Department. The owners shall submit to the Department a written proposal for such monitoring program on or before July 1, 1975.

g. A rule for limiting nitrogen oxides emission from existing fossil fuel steam generators will be developed by July 1, 1975.

3. New and existing Plants with 250 million or less BTU per hour heat input.

a. Visible emissions standards as set forth in item 17-2.04(6) (e) 1.b of this section.

b. Particulate matter, sulfur dioxide and nitrogen oxides apply 17-2.03 (1) latest technology.

4. Compliance Schedules

(i) Compliance schedules, SO2 Emissions for existing plants regulated by Section 17-2.04(6)(e) 2.c and d, Florida Administrative Code are repealed as of the effective date of this rule.

(ii) All fossil fuel steam generators, regardless of size, need not comply with any existing compliance schedule SO2 Emissions required by the Department, but shall as expeditiously as possible comply with the specific emission standards set forth in Subsection 17-2.04(6)(e) 2.c and d or, if applicable, Subsection 17-2.04(6)(e) 3, at option of the owner.

5. If at any time the Board determines, after notice and public hearing, that appropriate and substantially lower sulfur fuels are available on a long term basis at a reasonably comparable cost (including all costs such as contract revision or termination costs) with fuels allowed under this rule, the Board may establish revised emission limiting standards.

(f) Portland Cement Plants – the emission limiting standards for Portland Cement Plants are:

1. Existing and new sources.

a. For Kilns – particulate shall be not greater than allowed by the Process Weight Table. Table I. set forth in 17-2.04 (2). The table shall be applied to each individual source rather than being applied on the basis of mass emission limitations.

b. For clinker-coolers the emission limiting standard of 17-2.04 (6) (f) 1.a above apply.

(g) Nitric Acid Plants – the emission limiting standards for nitric acid plants producing weak nitric acid (50-70 percent) by pressure or atmospheric pressure process are:

1. New plants

a. Nitrogen oxides no greater than 3 pounds per ton of acid produced (100 percent basis)

b. Visible emissions – none permitted.

2. Existing plants shall comply with the standard as expeditiously as possible but no later than July 1, 1975.

(h) Sulfur Recovery Plants – the emission limiting standards for sulfur recovery plants recovering sulfur from crude oil gas are:

1. New Plants

a. Sulfur oxides calculated as sulfur dioxide – no greater than 0.004 pounds of SO_2 per pound of sulfur input to the recovery system or no greater than 0.004 pounds of SO_2 per pound of sulfur removed from an oil well.

2. Existing Plants.

a. For those sulfur recovery plants for which a valid Department Construction Permit was issued prior to July 1, 1973, the emission limiting standard shall be: no greater than 0.08 pounds of SO_2 per pound of sulfur input to the recovery system or no greater than 0.08 pounds of SO_2 per pound of sulfur removed from crude oil or gas processed.

(i) Carbonaceous fuel burning equipment.

A. The emission limiting standards for carbonaceous fuel burning equipment for which a valid Department operation or construction permit has been issued prior to July 1, 1974, are:

(1) Particulate

(a) For burners of capacity less than 30 million BTU/hr total heat input – no particulate limiting standard.

(b) For burners of capacity equal to or greater than 30 million BTU/hr – the particulate matter emitted shall not exceed the sum of 0.3 pound per million BTU of heat input of carbonaceous fuel and 0.1 pound per million BTU of fossil fuel.

(2) Visible Emissions

(a) For burners less than 30 million BTU/hr input – the visible emission or density shall not exceed Ringelmann I or an opacity of 20 percent except that a density of Ringelmann II is permissible for not more than two minutes in any hour.

(b) For burners of capacity equal to or greater than 30 million BTU/hr input – the visible emission or density shall not exceed Ringelmann 1.5 or an opacity of 30 percent except that a density of Ringelmann II or opacity of 40 percent is permissible for not more than two minutes in any hour.

B. New Sources – The emission limiting standards for carbonaceous fuel burning equipment for which a valid Department operation or construction permit is issued on or after July 1, 1974, are:

(1) Particulate

(a) For burners of capacity less than 30 million BTU/hr total heat input – no particulate limiting standard.

(b) For burners of capacity equal to or greater than 30 million BTU/hr – the particulate matter emitted shall not exceed the sum of 0.2 pound per million BTU of heat input of carbonaceous fuel and 0.1 poun per million BTU of fossil fuel.

(2) Visible Emissions

(a) For burners of capacity less than 30 million BTU/hr input – same as paragraph 2.04(6) (i) A (2) (a) above.

(b) For burners of capacity equal to or greater than 30 million BTU/hr input – same as paragraph 2.04(6) (i) A (2) (b).

(3) The Department shall provide for an annual review and evaluation of the particulate and visible emission standards applicable to new sources.

c. The above standards shall not relieve any person from complying with more stringent Department permit conditions promulgated pursuant to Section 403.087, Florida Statutes, and Department Rule 17-4.07(5), Florida Administrative Code.

(7) Mobile Sources

(a) No person shall cause, let, permit, suffer or allow the emission of smoke from motor vehicles on public roadways which is visible within the proximity of the engine exhaust outlet for a period of more than five (5) seconds.

1. Definitions – apply to this paragraph 17-2.04 (7) (a) only

a. Smoke is defined as small gasborne and airborne particles, exclusive of water vapor, from a process of combustion, in sufficient number to be observable.

b. Motor vehicle is defined as any device powered by an internal combustion engine and on or in which any person or property may be transported.

2. Exception – all 2 cycle gasoline engines manufactured prior to the year 1976.

(8) Complex Sources

(a) For the purposes of this section the following definitions shall apply:

1. "Complex Source" means any facility, or group of facilities, which is a source of air pollution by reason that it causes, directly or indirectly, significant increases or emissions of pollutants into the atmosphere or which reasonably can be expected to cause an increase in the ambient air concentrations of pollutants, either by itself or in association with mobile sources.

2. "Commencement of Construction" shall mean the actual on site, continuous and systematic activity of land surface alteration, construction, and fabrication of the source.

3. "Modification" means any physical change in the source which will result in the source causing or contributing to an increase of emissions to the ambient air.

(b) No person shall construct or modify or operate or maintain any complex source of air pollution which results in or causes an increase in ambient pollutant concentrations in violation of the Ambient Air Quality Standards.

(c) After December 15, 1973, no person shall commence construction or modification of any of the following listed complex sources without a permit from the Department, or other governmental agency authorized by the Department to issue such permit:

1. Any new complex source with which is associated a single level unenclosed parking facility with a design or use capacity of 1500 cars or more, or any modification

which will increase such unenclosed parking facility to a design or use capacity of 1500 cars or more.

2. Any multi-level unenclosed parking facility with a design or use capacity of 750 cars or more, or any modification which will increase a multi-level unenclosed facility to a design or use capacity of 750 cars or more.

3. Any new road designed to accommodate 2000 vehicles per hour or more at peak traffic flow rates, or a modification of an existing road the result of which is designed to accommodate 2000 vehicles or more at peak traffic flow rates.

4. Any new road or modification to accommodate 1000 vehicles per hour or more of peak traffic flow rates or a modification which results in a design capacity for accommodation of 1000 vehicles per hour or more of peak traffic flow rates in the following urban counties: Dade, Broward, Palm Beach, Brevard, Hillsborough, Pinellas, Orange, Duval, Escambia, Polk, Leon, Sarasota, Volusia, Alachua, Pasco and Lee.

5. All major tollways or interstate highways or other major roads of more than two lanes of traffic outside of the urban areas named in paragraph 4 above.

6. Any new airport which is designed or may be used to serve commercial airlines regularly scheduled or otherwise or any modification of a parking facility such an airport which results in a 10 percent increase in capacity.

7. If the Department finds after notice, and hearing, if requested, that projected emissions associated with any proposed complex source not listed above may result in the failure of the Ambient Air Quality Standards being achieved and maintained, the Department may require an application to be submitted and a permit required prior to construction.

(d) Any person seeking a permit shall submit such information that is necessary for the Department to make a determination that the complex source will not cause a violation of ambient air quality standards. Such information shall include, but not be limited to:

1. The nature and amounts of pollutants to be emitted or caused to be emitted by the complex source, or by associated mobile sources, and an air quality impact statement.

2. The location, design, construction and operation of such facility.

(e) No such permit shall be issued without an opportunity for public comment in accordance with Section 17-2.09, F.A.C.

(f) This subsection 17-2.04 (8), Florida Administrative Code shall not apply to air pollution sources for which a permit is required by Chapter 17-4, Florida Administrative Code, and shall not apply to sources for which the commencement of construction was prior to December 15, 1973, unless construction is, or has been discontinued for more than ninety days.

(g) Public Highway projects which would otherwise be covered by this section (17-2.08 (8)) and for which bid letting has been advertised prior to April 1, 1974 are exempted from the formal permitting requirements of this section provided, however, that the staffs of the State of Florida DOT and DPC will re-examine the environmental assessments for each project to identify those projects which will violate State ambient air quality standards. Those projects so identified will not be exempted from the permitting requirements of this section.

17-2.05 Ambient Air Quality Standards

(1) The air quality of the State's atmosphere is determined by the presence of specific pollutants in certain concentrations. Human health and welfare is affected and known or anticipated adverse results are produced by the presence of pollutants in excess of the certain concentrations. It is, therefore, established that maximum limiting levels, Ambient Air Quality Standards, of pollutants existing in the ambient air are necessary to protect human health and public welfare. The following statewide Ambient Air Quality Standards are established for Florida:

(a) Sulfur Dioxide

1. 60 micrograms per cubic meter (0.02 ppm) – annual arithmetic mean.

2. 260 micrograms per cubic meter (0.1 ppm) maximum 24 hour concentration, not to be exceeded more than once per year.

3. 1300 micrograms per cubic meter (0.5 ppm) maximum 3 hour concentration, not to be exceeded more than once per year.

(b) Particulate Matter

1. 60 micrograms per cubic meter – annual geometric mean.

2. 150 micrograms per cubic meter – maximum 24 hour concentration, not to be exceeded more than once per year.

(c) Carbon Monoxide

1. 10 milligrams per cubic meter (9 ppm) – maximum 8 hour concentration, not to be exceeded more than once per year.

2. 40 milligrams per cubic meter (35 ppm) – maximum 1 hour concentration, not to be exceeded more than once per year.

(d) Photochemical Oxidants – measured and corrected for interference due to nitrogen oxides and sulfur dioxide.

1. 160 micrograms per cubic meter (0.08 ppm) – maximum 1 hour concentration, not to be exceeded more than once per year.

(e) Hydrocarbons – For use as a guide in devising implementation plans to achieve oxidant standards. To be measured and corrected for methane.

1. 160 micrograms per cubic meter (0.24 ppm) maximum 3 hour concentration (6 to 9 a.m.) not to be exceeded more than once per year.

(f) Nitrogen Dioxide

1. 100 micrograms per cubic meter (0.05 ppm) annual arithmetic mean.

(2) Exception – in Dade, Broward, and Palm Beach County, the above Ambient Air Quality Standards apply except as provided differently below:

(a) Sulfur Dioxide

1. 8.6 micrograms per cubic meter (0.003 ppm) – annual arithmetic mean.

2. 28.6 micrograms per cubic meter (0.010 ppm) – 24 hour concentration.

3. 57.2 micrograms per cubic meter (0.020 ppm) – maximum four hour concentration.

4. 286 micrograms per cubic meter (0.100 ppm) maximum one hour concentration.

(b) Suspended Particulates

1. 50 micrograms per cubic meter – annual geometric mean.

2. 180 micrograms per cubic meter – maximum 24 hour concentration.

(c) Carbon Monoxide

1. 9 milligrams per cubic meter (8 ppm) – maximum 8 hour concentration.

2. 14 milligrams per cubic meter (12 ppm) – maximum 1 hour concentration.

(3) Sampling and analyses of contaminants in this section shall be performed by the methods approved by the Board.

(4) Abatement – a determination that any of the above standards, 17-2.05 (1), has been exceeded, shall be adequate evidence for the Department to commence an investigation to determine the cause and to execute appropriate remedial measures.

General Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061 FS. History – New 1-11-72.

17-2.06 *Air Pollution Episode*

An episode describes a condition which exists when meteorological conditions and rates of discharge of air pollutants combine to produce pollutant levels in the atmosphere which, if sustained, can lead to a substantial threat to the health of the people. In order to prevent episode conditions from continuing or from developing into more severe conditions, positive action and a rapid abatement response is necessary. The severity of an episode has been classified upon the basis of the criteria given in the following section with the three levels, alert, warning and emergency described.

Due to the exigent nature of named episodes the Director shall determine and declare that an air pollution episode exists. His determination shall be in accordance with the following criteria:

(1)(a) Air Pollution Forecast – the existence or forecast of a stagnant atmospheric condition as advised by a National Weather Service advisory is in effect or an equivalent state or local determination of a stagnant condition.

(b) "Alert" – the alert level is that concentration of pollutants at which first stage control actions is to begin. An "alert" shall be declared when any one of the following levels is reached at any monitoring site:

1. Sulfur Dioxide (SO_2) – 800 micrograms per cubic meter (0.3 ppm) 24 hour average.

2. Particulate – 3.0 COHs or 375 micrograms per cubic meter, 24 hour average.

3. Sulfur Dioxide (SO_2) and Particulate combined – product of SO_2 ppm, 24 hour average, and COHs equal to 0.2 or product of SO_2 micrograms per cubic meter, 24 hour average equal to 65 X 10^3.

4. Carbon Monoxide (CO) – 17 milligrams per cubic meter (15 ppm), 8 hour average.

5. Oxidant (O_3) – 200 micrograms per cubic meter (0.1 ppm) 1 hour average.

6. Nitrogen Dioxide (NO_2) – 1130 micrograms per cubic meter (0.6 ppm), 1 hour average, 282 micrograms per cubic meter (0.15 ppm), 24 hour average,

and meteorological conditions are such that pollutant concentrations can be expected to remain at the above levels for twelve (12) or more hours or increase unless control actions are taken.

(c) "Warning" – the warning level indicates that air quality is continuing to degrade and that additional control actions are necessary. A "warning" shall be declared when any one of the following levels is reached at any monitoring site:

1. Sulfur Dioxide (SO_2) – 1600 micrograms per cubic meter (0.6 ppm), 24 hour average.

2. Particulate – 5.0 COHs or 625 micrograms per cubic meter, 24 hour average.

3. Sulfur Dioxide (SO_2) and Particulate combined – product of SO_2 ppm, 24 hour average and COHs equal to 0.8 or product of SO_2 micrograms per cubic meter, 24 hour average and particulate micrograms per cubic meter, 24 hour average equal to 261 X 10^3.

4. Carbon Monoxide (CO) – 34 milligrams per cubic meter (30 ppm), 8 hour average.

5. Oxidant (O_3) – 800 milligrams per cubic meter (0.4 ppm) – 1 hour average.

6. Nitrogen Dioxide (NO_2) – 2260 milligrams per cubic meter (1.2 ppm) – 1 hour average; 565 milligrams per cubic meter (0.3 ppm), 24 hour average,

and meteorological conditions are such that pollutant concentrations can be expected to remain at the above levels for twelve (12) or more hours or increase unless control actions are taken.

(d) "Emergency" – the emergency level indicates that air quality is continuing to degrade to a level that should never be reached and that the most stringent control actions are necessary. An "emergency" shall be declared when any one of the following levels is reached at any monitoring site:

1. Sulfur Dioxide (SO_2) – 2,100 micrograms per cubic meter (0.8 ppm), 24 hour average.

2. Particulate – 7.0 COHs or 875 micrograms per cubic meter 24 hour average.

3. Sulfur Dioxide (SO_2) and Particulate combined – product of SO_2 ppm, 24 hour average and COHs equal to 1.2 or product of SO_2 micrograms per cubic meter, 24 hour average and particulate micrograms per cubic meter 24 hour average equal to 393 X 10^3.

4. CO – 46 milligrams per cubic meter (40 ppm), 8 hour average.

5. Oxidant (O_3) – 1,200 micrograms per cubic meter (0.6 ppm), 1 hour average.

6. Nitrogen Dioxide (NO_2) – 3,000 micrograms per cubic meter (1.6 ppm), 1 hour average; 750 micrograms per cubic meter (0.4 ppm), 24 hour average,

and meteorological conditions are such that pollutant concentrations can be expected to remain at the above levels for twelve (12) or more hours

(e) Area of Episode. The Director shall, when declaring any expisode level, declare the counties in which the episode exists.

(f) "Termination" – once declared, any episode level will remain in effect until the pollutant concentration increases to meet the next higher level criteria or decreases to a point below the declared criteria level.

(2) (a) Emission Reduction Plans and Actions.

Upon a declaration by the Director that any episode level exists – alert, warning, or emergency – any person responsible for the operation or conduct of activities which result in emission of air pollutants shall take actions as required for such source or activity for the declared episode level as set forth in Episode Tables I, II, and III of this section and shall put into effect the Preplanned Abatement Strategy.

EPISODE TABLE I

Alert Level Emission Reduction Plans

Part A. General

During an "alert" level episode:

1. All forms of open burning are prohibited.

2. The use of incinerators for disposal of any form of solid waste or liquid waste is prohibited.

3. Persons operating fuel-burning equipment which requires boiler lancing or soot blowing shall perform such operations only between the hours of 12 noon and 4 p.m.

4. Persons operating motor vehicles should eliminate all unnecessary operations.

Part B. Source Curtailment

During an alert level episode any persons responsible for the operation of a source of air pollutants listed below shall take all required control actions for this alert level:

Source of Air Pollution:

1. Coal or oil-fired electric power generating facilities.

Required Control Action:

a. Substantial reduction by utilization of fuels having low ash or sulfur content.

b. Maximum utilization of mid-day (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing and soot blowing.

c. Substantial reduction by diverting electric power generation to facilities outside of alert area.

Source of Air Pollution:

2. Process steam generating facilities which fire coal or oil.

Required Control Action:

a. Substantial reduction by utilization of fuels having low ash and sulfur content.

b. Maximum utilization of mid-day (12 noon to 4 p.m.) atmospheric turbulence of boiler lancing and soot blowing.

c. Substantial reduction of steam demands consistent with continuing plant operations.

Source of Air Pollution:

3. Process steam generating facilities which fire wood, bark, or bagassee: totally or in combination with other fuels.

Required Control Action:

a. Substantial reduction by switching to fossil fuels with low ash and sulfur content or by diverting steam demands to steam generators utilizing low ash and sulfur content fuels.

b. Maximum utilization of mid-day (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing and soot blowing.

c. Substantial reduction of steam demands consistent with continuing plant operations.

Source of Air Pollution:

4. Manufacturing industries of the following classifications:

Pulp and paper industries
Citrus industries
Mineral Processing industries
Phosphate and allied chemical industries
Secondary metal industry
Petroleum operations

Required Control Action:

a. Substantial reduction of air pollutants from manufacturing operations by enacting preplanned abatement strategies including curtailing postponing or deferring production and all operations.

b. Curtail trade waste disposal operations which emit air pollutants.

Source of Air Pollution:

5. Bulk handling operations which transfer or store material including but not limited to:

Cement
Fertilizer
Phosphate rock
Grain or Feed
ROP Triple Super Phosphate
Lime
Sand and Gravel
Dolomite

Required Control Action:

a. Maximum reduction of fugitive dust by curtailing, postponing or deferring bulk handling operations.

Source of Air Pollution:

6. Any other industrial or commercial establishments which emit air pollutants.

Required Control Action:

a. Substantial reduction of air pollutants by curtailing, postponing, or deferring operations.

b. Curtail trade waste disposal operations which emit air pollutants.

EPISODE TABLE II

Warning Level Emission Reduction Plans

Part A. General

During a "Warning" level episode:

1. All forms of open burning are prohibited.

2. The use of incinerators for disposal of any form of solid waste or liquid waste is prohibited.

3. Persons operating fuel burning equipment which requires boiler lancing or soot blowing shall perform such

operations only between the hours of 12 noon and 4 p.m.

4. Persons operating motor vehicles must reduce operations by the use of car pools and increased use of public transportation and elimination of unnecessary operation.

5. Unnecessary space heating or cooling is prohibited.

Part B. Source Curtailment

During a warning level episode any persons responsible for the operation of a source of air pollutants listed below shall take all required control actions for this warning level:

Source of Air Pollution:

1. Coal or oil-fired electric power generating facilities.

Required Control Action:

a. Maximum reduction by utilization of fuels having lowest ash and sulfur content.

b. Maximum utilization of mid-day (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing and soot blowing.

c. Maximum reduction by diverting electric power generation to facilities outside of warning area or to generating stations emitting less pollutants per kilowatt generated.

Source of Air Pollution:

2. Process steam generating facilities which fire oil or coal.

Required Control Action:

a. Maximum reduction by utilization of fuels having the lowest available ash and sulfur content.

b. Maximum utilization of mid-day (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing and soot blowing.

c. Stand-by to enact preplanned emergency action plan.

Source of Air Pollution:

3. Process steam generating facilities which fire wood, bark or bagassee.

Required Control Action

a. Maximum reduction by reducing heat and steam demands to absolute necessities consistent with preventing equipment damage.

b. Maximum utilization of mid-day (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing and soot blowing.

Source of Air Pollution:

4. Manufacturing industries of the following classifications:

Pulp and paper industries
Citrus industries
Mineral processing industries
Phosphate and allied chemical industries
Secondary metal industry
Petroleum operations

Required Control Actions:

a. Commence preplanned abatement strategies for the elimination of all air pollutants.

b. Elimination of air pollutants from trade waste disposal operations which emit air pollutants.

Source of Air Pollution:

5. Bulk handling operations which transfer or store material including but not limited to:

Fertilizer
Phosphate Rock
Grain or Feed
ROP Triple Super Phosphate
Cement
Lime
Sand and Gravel
Dolomite

Required Control Action:

a. Elimination of fugitive dust by ceasing, curtailing, postponing or deferring transfer or storage of material.

Source of Air Pollution:

6. Any other industrial or commercial establishments which emit air pollutants.

Required Control Action:

a. Maximum reduction by curtailing, postponing or deferring operations.

b. Eliminate trade waste disposal operations which emit air pollutants.

EPISODE TABLE III

Emergency Level Emission Reduction Plans

Part A. General

During an "emergency" level episode:

1. All forms of open burning are prohibited.

2. The use of incinerators for disposal of any form of solid or liquid waste is prohibited.

3. All places of employment described below shall immediately cease operations.

a. Mining and quarrying of nonmetallic minerals.

b. All construction work except that which must proceed to avoid emergent physical harm.

c. All manufacturing establishments except those required to have in force an air pollution emergency plan.

d. All wholesale trade establishments; i.e., places of business primarily engaged in selling merchandise to retailers, or industrial, commercial, institutional or professional users, or to other wholesalers, or acting as agents in buying merchandise for or selling merchandise to such persons or companies, except those engaged in the distribution of drugs, surgical supplies and food.

e. All offices of local, county and State government including authorities, joint meetings, and other public bodies excepting such agencies which are determined by the chief administrative officer of local, county, or State government, authorities, joint meetings and other public bodies to be vital for public safety and welfare and the enforcement of the provisions of this order.

f. All retail trade establishments except pharmacies, surgical supply distributors, and stores primarily engaged in the sale of food.

g. Banks, credit agencies other than banks, securities and commodities brokers, dealers, exchanges and services; offices of insurance carriers, agents and brokers, real estate offices.

h. Wholesale and retail laundries, laundry services and cleaning and dyeing establishments, photographic studios; beauty shops, barber shops, shoe repair shops.

i. Advertising offices; consumer credit reporting, adjustment and collection agencies; duplicating, addressing, blueprinting; photocopying, mailing, mailing list and stenographic services; equipment rental services, commercial testing laboratories.

j. Automobile repair, automobile services, garages.

k. Establishments rendering amusement and recreational services including motion picture theaters.

l. Elementary and secondary schools, colleges, universities, professional schools, junior colleges, vocational schools, and public and private libraries.

4. All commercial and manufacturing establishments not included in this section will institute such actions as will result in maximum reduction of air pollutants from their operation by ceasing, curtailing or postponing operations which emit air pollutants to the extent possible without causing injury to persons or damage to equipment.

5. The use of motor vehicles is prohibited except in emergencies with the approval of local or state police.

6. Unnecessary lighting, heating or cooling in unoccupied structures is prohibited.

Source of Air Pollution:

1. Coal or oil-fired electric power generating facilities.

Required Control Action:

a. Maximum reduction by utilization of fuels having lowest ash and sulfur content.

b. Maximum utilization of mid-day (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing or soot blowing.

c. Maximum reduction by diverting electric power generation to facilities outside of emergency area or to generating stations emitting less pollutants per kilowatt generated.

Source of Air Pollution:

2. Coal, oil, natural gas, wood, bark and bagassee – fired process steam generating facilities.

Required Control Action:

a. Maximum reduction by reducing heat and steam demands to absolute necessities consistent with preventing equipment damage.

b Maximum utilization of mid-day (12 noon to 4 p.m.) atmospheric turbulence for boiler lancing or soot blowing.

c. Taking the action called for in preplanned emergency action plan.

Source of Air Pollution:

3. Manufacturing industries of the following classifications:

Pulp and paper industries
Citrus industries
Mineral processing industries
Phosphate and allied chemical industries
Secondary metal industries
Petroleum operations

Required Control Action:

a. Continuation of preplanned abatement strategies for the elimination of air pollutants.

b. Elimination of air pollutants from trade waste disposal operations which emit air pollutants.

Source of Air Pollution:

4. Bulk handling operations which transfer or store material including but not limited to:

Cement
Fertilizer
Phosphate Rock
Grain
ROP Triple Super Phosphate
Lime
Sand and Gravel
Dolomite

Required Control Action:

a. Elimination of fugitive dust by ceasing, curtailing, postponing or deferring transfer or storage of material.

Source of Air Pollution:

5. Any other industrial or commercial establishments which emit air pollutants.

Required Control Action:

a. Elimination of air pollutants by ceasing, curtailing, postponing or deferring operations.

b. Elimination of air pollutants from trade waste disposal process which emit air pollutants.

(b) Preplanned Abatement Strategies – any person responsible for one or more air pollutant sources shall prepare and submit, upon written request from the Department, a stand-by plan which describes the action which will be taken by that person to reduce emissions when an episode is declared. The plan shall be submitted within 30 days of the request and will be subject to approval, modification or rejection by the Department. The plan shall be in writing and shall include but not be limited to:

1. Identity and location of pollutant sources and of contaminants discharged.

2. Approximate amount of normal emission and of reduction of emission expected.

3. A brief description of the manner in which reduction will be achieved, for each of the episode levels, alert, warning and emergency.

(c) Whenever during an episode (alert, warning, or emergency) any person responsible for the operation of a source or conduct of activities which result in emission of air pollutants does not take actions as required for the source or activity for the declared episode level or put into effect the Preplanned Abatement Strategy, the Director shall immediately institute proceedings in a court of competent jurisdiction for injunctive relief to enforce this chapter.

General Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061 FS. History – New 1-11-72.

17-2.07 *Sampling and Testing*

(1) All persons shall, upon request of the Department, provide continuous automatic monitoring testing and records of contaminants being emitted from a source.

(2) All persons shall provide facilities for continuously determining the input process weight or input heat when such factors are the basis for limiting standards.

(3) A person responsible for the emission of air pollut-

ants from any source shall, upon request of the Department provide in connection with such sources and related source operations, such sampling and testing facilities exclusive of instruments and sensing devices as may be necessary for the proper determination of the nature and quantity of air pollutants which are, or may be emitted as a result of such operation.

(4) Such facilities may be either permanent or temporary at the discretion of the person responsible for their provision and shall be suitable for the use of methods and equipment acceptable to the Department, who shall indicate in writing the required size, number and location of sampling holes; the size and location of the sampling platform; and the utilities for operating the sampling and testing equipment. The facilities shall comply with all applicable laws and regulations concerning safe construction and safe practice in connection with such facilities.

(5) When the Department upon investigation has good reason to believe that the provisions of this chapter concerning emission of pollutants are being violated, it may require the person responsible for the source of pollutants to conduct tests which will identify the nature and quantity of pollutant emissions from the source and to provide the results of said tests to the Department. These tests shall be carried out under the supervision of the Department, and at the expense of the person responsible for the source of pollutants.

(6) All analyses and tests shall be conducted in a manner specified by the Department. Results of analyses and tests shall be calculated and reported in a manner specified by the Department.

(7) Analyses and tests for compliance may be performed by the Department at the cost of the person responsible for the emission of air pollutants.

General Authority 403.061, 403.101 FS. Law Implemented 403.021, 403.031, 403.061, 403.101 FS. History – Revised 1-11-72.

17-2.08 *Local Regulations.* Regulations controlling air pollution may be adopted by local governmental authorities provided that such regulations shall not be in conflict herewith or that standards so adopted shall not be less stringent than those established herein.

General Authority 403.061, 403.182 FS. Law Implemented 403.021, 403.031, 403.061, 403.182 FS. History – Formerly 17-2.09, FAC.

17-2.09 *Public Comment*

(1) Before any department permit is issued for any source of air pollution the department shall provide an opportunity for public comment which shall include as a minimum the following:

(a) Availability for public inspection in at least one location in the region affected the information submitted by the owners or operator and the Department's analysis of the effect of such construction or modification on ambient air quality, including the Department's proposed approval or disapproval.

(b) A 30-day period for submittal of public comment; and

(c) A notice by prominent advertisement in the region affected, specifying the nature and location of the proposed source and that the information specified in subsection 17-2.09 (1) (a), F.A.C. is available for public inspection at a designated location.

(d) A copy of the notice shall also be sent to the U.S. Environmental Protection Agency through the appropriate regional office, and to all other state and local air pollution control agencies having jurisdiction in the region in which such new or modified installation will be located. The notice also shall be sent to any other agency in the region having responsibility for implementing the department's permit program.

(e) A copy of the notice shall be displayed in the appropriate Regional, Subregional, and Local Program offices.

(2) Because public comment or lack of same is vital information to a proper determination of a permit application, the Department shall not make a final decision on the application until the time period for public comment has expired, but shall make the final determination within sixty days thereafter.

17-2.10 *Local Government*

No municipality or political subdivision of the state shall issue any building or other permit to construct or modify a source of air pollution for which a permit is required by department rule unless the source has received a valid department permit.

17-2.12 *Source Testing Method*

Air Pollutant emissions shall be tested and analyzed in accordance with the *Standard Sampling Techniques and Methods of Analysis for the Determination of Air Pollutants from Point Sources*, January, 1974, as adopted by the Board and as may be amended from time to time by the Board.

APPENDIX D. THE STACK GAS DISPERSION MODEL

The model used to estimate ambient concentrations for the phosphate rock processing plant is one developed by the Meteorology Laboratory of the EPA. This model is designed to estimate concentrations due to sources at a single location for averaging times from 1 hour to 1 year.

This model is a Gaussian plume model using diffusion coefficients suggested by Turner (1970).* Concentrations are calculated for each hour of the year from observations of wind direction (in increments of 10 degrees), wind speed, mixing height, and atmospheric stability. The atmospheric stability is derived by the Pasquill classification method as described by Turner (1970). In the application of this model, all pollutants are considered to display the dispersion behavior of nonreactive gases.

Meteorological data for 1964 are used as input to the model. The reasons for this choice are (1) data from earlier years did not have sufficient resolution in the wind direction, and (2) data from subsequent years are readily available on magnetic tape only for every third hour.

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* Turner, D.B. Workbook of Atmospheric Dispersion Estimates. U.S. DHEW. PHS Publication No. 999-AP-24. (Revised 1970).

Mixing height data are obtained from the twice-a-day upper air observations made at the most representative upper air station. Hourly mixing heights are estimated by the model, using an objective interpolation scheme.

A feature of this model is the modification of plume behavior to account for aerodynamic effects for plants in which the design is not optimal. Another important aspect of the model is the ability to modify concentration to account for the physical separation between the stacks since all are assumed to be located at the same geographical point.

Calculations are made for 180 receptors (at 36 azimuths and 5 selectable distances from the source). The JMHCRD-1 model used here can consider both diurnal and seasonal variations in the source. Separate variation factors can be applied on a monthly basis to account for seasonal fluctuations and on an hourly basis to account for diurnal variations. Another feature of the model is the ability to compute frequency distributions for concentrations of any averaging period over the course of a year. Percentages of various ranges in pollutant concentrations are calculated.

AERODYNAMIC-EFFECTS MODIFICATION OF THE SINGLE SOURCE MODEL

Note: The aerodynamic-effects version is a more general form of the single source model. All remarks made in Appendix B apply equally to either version.

The single source model does not address the aerodynamic complications that arise when plant design is less than ideal. These effects result from the interaction of the wind with the physical structure of the plant. Such interaction can retard or, in the extreme, prevent plume rise. The extreme case is commonly referred to as "downwash." With downwash, the effluent is brought downward into the wake of the plant, from which point it diffuses as though emitted very close to the ground. In the retardation case, some of the dispersive benefits of plume rise are lost; whereas in the downwash case, all of the benefits of plume rise are lost, along with most of the benefits of stack elevation. Both phenomena--but especially downwash--can seriously increase the resulting ambient air impact.

The aerodynamic-effects modification is an attempt to include these effects in a predictive model. It was developed within EPA and, while not yet validated, is the best-known operational approach. Basically, it enables the model to make an hour-by-hour, stack-by-stack assessment of the extent of aerodynamic complications. The parameters used in making the assessment are wind speed, stack gas exit velocity, stack height, stack diameter, and building height. If a particular assessment indicates no aerodynamic effect for a specific stack and time, the model behaves just like the unmodified version. If there are aerodynamic effects, the modified version contains equations by which the impact of these effects on ground-level concentrations is estimated.